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INDUSTRIAL WASTELINE STUDY. A SYSTEM FOR CONTROLLED OCEAN DISPOSAL

Daniel Pindzola, et al

Franklin Institute Research Laboratories

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Report

INDUSTRIAL WASTELINE STUDY - A SYSTEM FOR CONTROLLED OCEAN DISPOSAL

By

Daniel Pindzola
Charles T. Davey
Robert A. Erb

Covering Period 1 July 1969 to 1 August 1970

Prepared for

FEDERAL WATER QUALITY ADMINISTRATION
United States Department of The Interior
Washington, D.C. 20242

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27 Abstract

Pipelining waste to the edge of the continental shelf from the Delaware Valley was found to be feasible by defining waste loads, routes, pipe types, conditions of the proposed outfall area and costs. The waste load was examined and projected by type and quantity by percent of total volume as follows: dredge spoils, 24%; sewage sludges, 6%; waste acids and chemicals, 6%; ashes, 0.3%; and dilute industrial waste, 63.7%. Present dilute volume is established at 5,840 million gallons per year.

Routes may generally be obtained along power and rail lines currently existing. Of pipe materials considered, polyester-glass reinforced pipe appears best for overland routing and polyolefin for undersea. Estimated installation costs are in the area of $75,000,000. Disposal costs could be reduced from the current $3.50 to $1.85 per 1000 gallons.

Ocean studies included otter trawls and direct observation by submersible which showed the biodensity to fall off with increasing depth. The proposed disposal area appears less densely populated than inshore areas and less productive than bays, marshes and estuaries where wastes are currently deposited.

Bottom currents were determined to be mainly off shore by current meters and seabed drifters. Of 400 seabed drifters deposited, only two were recovered, these by commercial trawlers. Dissolved oxygen levels were high in the water column. Further ~~examination and baseline data are needed. Actual pilot construction would be desirable.~~

Abstractor ~~Charles T. Davey~~ Institution ~~The Franklin Institute~~ (EPA)

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FOREWORD

The work reported here was started as the result of an idea aimed at the elimination or minimizing certain waste problems now facing our nation. During the course of the work some of the initial concepts of the disposal system changed to some extent, but never to the abandonment of the basic idea. It is not now apparent that any of the alternative means of disposal existing at the start of this work are more tenable than the pipeline to the sea or that alternate solutions (e.g., burning of municipal sludge, deposition of dredge spoil on marshlands) provide for a better overall environment.

In all fiarness to the workers on this program, it must be stated that more data collection, study and analysis were anticipated at the close of this program and that all results of this and related work were not completed.

Our hopes are that the findings reported here will be of use in some future effort for they represent many man-hours of mal de mer as well as many rewarding experiences that are a part of Ocean Studies.

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1. INTRODUCTION

Under the joint sponsorship of the Federal Water Quality Administration and the Pennsylvania Science and Engineering Foundation, the Franklin Institute Research Laboratories conducted studies to determine the technical, economic, and ecological feasibility of collecting and delivering waterborne waste concentrates from the Philadelphia Region to a point in the ocean beyond the edge of the continental shelf. Preliminary study indicated that a pipeline would be the best method of transporting these wastes for economic reasons. There are now indications that a single well managed and controlled system, such as a pipeline delivering wastes to these deep offshore bottom waters, would be desirable for ecological reasons as well.

The following report presents a summary of the nature of the studies conducted and the principal results derived from these studies.

The basic intent of the concept being explored is to return unusable residues and heterogeneous concentrates of polluting waterborne wastes to the environment in an effective and controlled manner, so that damaging environmental and ecological disruptions do not occur.

Presently such wastes are being buried, burned, or dumped directly into the Delaware River, its estuary or shallow near-shore waters of the continental shelf where important ground and surface water supplies and highly valuable river, estuarine, and near-shore eco-systems exist.

To date the study has explored the following aspects:

1. Definition of Waste Types and Volumes
2. Pipeline Routes
3. Piping Requirements
4. Auxiliary System Components

5. Disposal on the Upper Continental Slope
   - Hydrography
   - Biology and Chemistry
6. Legal Implications
7. Alternatives
8. Costs

This year's study has concentrated on defining the waste types and volumes and studying the basic concept of disposal on the upper continental slope region. The engineering, legal, and economic feasibility of the program have been investigated and a baseline study has been made on the hydrography, biology, and physical chemistry of the slope region. These data are a vital part of the ecological feasibility studies which had been proposed for the following year but were not funded.

2. SUMMARY

It has been found that dredge spoils, sewage sludges, industrial chemicals and a relatively small volume of assorted ashes constitute the major potential sources of concentrated waterborne pollutants available for disposal by pipeline system. The abnormally large volume of dredge spoils present in the relatively inland Philadelphia Region make it the undisputed top source of waterborne waste concentrates. Sewage sludge volume and waste chemicals follow, each with only one-quarter the volume of the dredge spoils. The ash volume produced in the Region has probably decreased in the last two years as low sulfur oil has displaced coal as an industrial fuel. A large volume of dilute waste will need to be added to the system to thin out the waste mixture.

Strong advantages appear to exist for using the dredge spoils, regularly available in large volume, as a diluent for the other waste components. The spoils would substantially stabilize the line's size and operation, pre-dilute and reduce the corrosiveness and ultimate reactivity of other waste inputs, and make the effluent denser than seawater. The latter would aid in the dispersal of the pre-diluted wastes in the bottom waters on the continental slope.

Many existing parallel routes are available for the pipeline from its input station just South of Camden, N.J. to its land terminus at Atlantic City. A combination of rail and electric transmission line paths appears most suitable.

Materials being tested and considered for the system include polyester-fiber reinforced pipe and polyolefin pipe.

Ocean studies on the biology, hydrography, and chemistry indicate that the area of the continental slope is less populated with benthic epifauna than currently-used disposal areas. Currents are

generally off-shore in this region, and waters are generally highly oxygenated, even at great depths.

Costs for delivering wastes the entire 160 miles to the shelf-break are less than for barging as at present and appear to have the technical advantage of totally controlled 24-hour-a-day operation.

3. DEFINITION OF WASTE TYPES AND VOLUMES

A major task of the study essential for the design of the entire system and for comparison and correlation with the chemistry and biology of the continental slope environment, has been to define the suitable types and volumes of wastes prevalent in the Region.

A prime emphasis in the survey has been placed on finding industrially generated waterborne wastes which have relatively high concentrations (i.e., greater than 0.5%) or wastes which might readily be concentrated. It was recognized that industrial wastes could be responsible for a disproportionate share of water pollution, far in excess of their actual volume or any other apparent measure of potency. For example, a relatively small volume of a select industrial waste could be upsetting to the operation of a municipal treatment plant. In addition, there are many well known instances where a momentary discharge or accidental spill of an industrial waste into fresh or estuarine water has affected the quality and ecology of these waters for considerable periods of time and for considerable distances downstream.

In order to avoid the removal of large volumes of fresh water from the Delaware River Basin and to minimize the pipe size required, it was determined that only concentrated forms of waterborne wastes should be taken by the system. Pipe and pipe laying costs rise sharply with increasing pipe diameter, particularly for pipe size above approximately 3 feet in marine applications.

3.1 Sources of Information

Information of wastes in the Philadelphia Region was obtained from direct interviews with personnel at the following federal, state, and municipal agencies involved in water and waste management:

The Philadelphia Regional FWQA Office
Delaware River Basin Commission
U.S. Army Corps of Engineers, Philadelphia District
Pennsylvania Department of Health
Philadelphia Water Department

and from interviews with pollution control officers and representatives of the petroleum, chemical, paper, and steel companies, which constitute the principal sources of industrial waste discharges in the region (See Table 1 for listing). Analysis of interview data collected during the 1964 FWQA Delaware Estuary Comprehensive Study (DECS) and Delaware River Basin Discharge Allocations for 1968 revealed that the bulk of the waterborne discharges in the Region came from these top 30 dischargers.

In addition to the above interviews, discussions were held with waste consultants and a large waste collection company who have dealt with Regional industrial waste problems for a number of years.

Other indirect sources of information were also utilized. These included Regional distributors of waste concentrating equipment (filters and centrifuges) and distributors of flocculents and adsorbents used in product recovery and waste treatment, and suppliers or filter aid materials. The latter all had excellent contact and information on sources of concentrated waterborne wastes in the Region.

From all of these sources of information, it was possible to construct a realistic and relatively comprehensive picture of the waterborne waste situation in the Region.

3.2 Results of Survey

Data on waterborne waste concentrates in the Region physically appropriate for ocean disposal by pipeline were found in the following major categories:

1. Dredge Spoils
2. Digested Sewage Sludges

Table 1

DELAWARE RIVER BASIN COMMISSION FINAL ALLOCATIONS FOR THE DELAWARE RIVER ESTUARY AS OF JUNE 1968: TOP THIRTY DISCHARGERS RANKED BY RAW-LOAD COD

Raw-Load Ranking	Type of Discharger*	Discharger	Raw-Load COD (lb/day)	Permissible Discharge COD (lb/day)	Required % Removal
1	M	Philadelphia - NE, Pa.	495,000	69,300	86.0
2	M	Philadelphia - SW, Pa.	270,000	29,000	89.3
3	M	Philadelphia - SE, Pa.	237,000	32,200	86.0
4	I	DuPont - Chambers, Deepwater, N.J.	169,000	21,100	87.5
5	I	Sun Oil - Sunolin, Marcus Hook, Pa.	114,900	14,400	87.5
6	M	Wilmington, Delaware	107,500	13,400	87.5
7	I	Rohm & Haas, Bristol, Pa.	91,670	2,750	97.0
8	I	DuPont - Repauno, Gibbstown, N.J.	91,200	9,800	89.3
9	M	Camden - Main, N.J.	85,000	11,900	86.0
10	I	Atlantic Oil IW, Phila., Pa.	61,000	6,560	89.2
11	I	Monsanto, Bridgeport, N.J.	40,800	4,390	89.2
12	I	Mobil Oil, Paulsboro, N.J.	39,500	4,250	89.2
13	M	Darby Creek SA, Pa.	37,200	4,000	89.2
14	I	Scott Paper, Chester, Pa.	34,900	3,750	89.3
15	I	Atlas Chemical New Castle, Del.	34,450	4,310	87.5
16	I	Getty Oil, Delaware City, Del.	29,700	2,500	91.6
17	I	Gulf Oil, IW, Philadelphia, Pa.	27,100	2,910	89.3
18	M	Chester, Pa.	26,300	2,830	89.2
19	I	Sinclair, Trainer, Pa.	24,650	2,650	89.2
20	M	Central Delaware Co. S.A.	24,600	2,640	89.3
21	I	Ruberoid, Gloucester City, N.J.	24,500	3,430	86.0
22	I	Hercules Powder, Gibbstown, N.J.	23,100	2,480	89.3
23	M	Lower Bucks MA, Pa.	20,930	2,410	88.5
24	M	Trenton, N.J.	20,400	2,350	88.5
25	I	Mac Andrews & Forbes, Camden, N.J.	19,450	2,720	86.0
26	I	U.S. Steel I.W., Fairless Hills, Pa.	18,330	2,110	88.5
27	M	Hamilton, N.J.	13,410	1,540	88.5
28	M	Muskinipattus, Pa.	12,850	1,380	89.3
29	I	Georgia-Pacific, Delair, N.J.	11,600	1,620	86.0
30	M	Pennsauken Township, N.J.	10,900	1,530	86.0
		TOTALS:	2,216,940	267,210	
		AVERAGE			87.9

*M = Municipal, total 13
I = Industrial, total 17

3. Waste Acids and Waste Chemicals
4. Ashes

Two other large sources of concentrated wastes found to be potentially available in the future were:

1. Raw Water Sediments and Coagulants and
2. Sulfur Dioxide Recovery Sludges

All listed waste materials, except sulfur dioxide recovery sludges are firmly existent sources.

While raw water sediments in most cases are presently backflushed into surface waters they will soon be backflushed and routed to sewage treatment plants where they can be collected along with sewage sludge.

The most striking and significant finding of the entire waste survey was that of the uniqueness and great magnitude of the dredge spoil disposal problem in the Philadelphia Region. While dredge spoils are a leading disposal problem in many regions, the problem in the Delaware Valley far exceeds that of New York, Baltimore, Norfolk or any other near-by region. The volume and concentration of dredge spoils, regularly 1.4 billion gallons per year at 42 Wt. % solids, exceeded that of all other sources of concentrated waterborne wastes in the Region. Dredge spoils would potentially constitute two-thirds of the volume input of concentrated wastes.

It was at first contemplated that the dredge spoil situation might be considered as an entirely separate disposal problem. However, after complete consideration of the entire system, it became clear that very significant advantages in design and operation of an ocean wasteline would result if the Regional spoil disposal problem was combined and simultaneously solved with the disposal problem of other industrial and municipal waste concentrates.

The outstanding benefits that are apparent from including dredge spoils in an ocean wasteline system are:

1. Substantial *pre-dilution* of all industrial wastes would occur in the line before release to the ocean.
2. The spoils would *neutralize* some corrosive and reactive waste inputs.
3. Wasteline effluent would have a density greater than that of sea water. Therefore, the effluent *would move downslope* while being dispersed and diluted, rather than rise towards surface waters where there could be a chance of coming into contact with surface fishing (long-lining) which occasionally occurs in the slope region.
4. Dredge spoils would be *permanently* removed from the Region.
5. *Pollution* and *consumption* of valuable riverine and estuarine marshland that are used as spoil grounds would be eliminated.
6. Wasteline size and operation would be substantially *stabilized* by having a major component a material which does not significantly fluctuate annually and which easily could be used to balance out monthly, seasonal, and annual fluctuations of other waste components.

A summary of the volumes found for the principal waterborne waste concentrates in the Delaware Valley Region is given in Table 2. Wastes are tabulated at their presently generated levels of volume and concentration. (Details on each category are given in the sections which immediately follow).

Analysis of the data clearly indicated that dilution of the concentrated wastes would be necessary from their overall received concentration of 30.4% in order to increase their fluidity.

Data on pumping dredge spoils, the major component of the system, hence the best probable indicator of system behavior, showed that a two fold dilution which reduced spoil concentration from ca. 40% to 20% would be adequate[3].

Extensive data on handling sewage sludges, the next largest but appreciably smaller component of the system, indicated that dilution to below 5% is required to achieve Newtonian flow[6].

Table 2

VOLUMES AND COMPOSITIONS OF CONCENTRATED WASTE SOURCES AVAILABLE FOR OCEAN PIPELINE DISPOSAL

Total Flow Volume: 16 mgd (5,840 mgy)

Component	Major Ingredients	Volume (mgy)	Volume % of Total	Solids Content[3] (Wt. %)
1. Dredge Spoils	Predominantly fine clays (Illite, chlorite, kaolinite and montmorillonite), fine quartz and feldspar, and small fraction of organic material	1,414	24	40
2. Sewage Sludges[1]	Organics: Cellulosics-Proteins-Fats Inorganics: SiO_2, Fe_2O_3m NH_4NO_3, PO_4, K+	337	6	10
3. Waste Acids and Waste Chemicals	HCl, H_2SO_4, $FeSO_4$, $FeCL_3$ Mixed organic chemicals, acids, and salts Filter aid materials and assorted chemical sludges	340	6	3
4. Ashes	Fly Ash, Incinerator Top Ash, Assorted Bottom Ashes	18[2]	0.3	3
5. Selected Dilute Industrial Waste	(used to increase fluidity of pipeline contents)	3,731	63.7	<0.5
TOTALS		5,840	100.0	12.3[4]

[1] Includes raw water sediments and coagulants

[2] 2,500 Tons of ash per year represented as a hypothetical 3% suspension

[3] Solids content in each component stream

[4] Weighted average of mixed stream.

Using the above data as guidelines, it was determined that for a basically sound yet flexible design, dilution of the system to a concentration of approximately 10% would be made. The suitability of this concentration level and limits of operability would be determined by actual experiments using waste mixtures.

Dilution of the waste concentrates would be effected by using selected dilute industrial wastes which are either a problem to treat or to concentrate. This would constructively take care of these troublesome materials.

It is expected that a somewhat flexible design basis would be required for a waste handling system. This is necessary in order to accomodate periodic changes in the quantity and nature of waste inputs. (e.g., operation at a 15-20% solids loading might be possible much of the time, while inputs of certain flocculated industrial sludges might require dilution to perhaps 5%).

Dilution of the concentrated wastes from 30.4% to 12.3% gives a line flow of 16 million gallons per day or 5,840 million gallons per year. This flow could easily be handled by a 30 to 36 inch pipeline. Using 36 inch pipe the flow velocity would be approximately 2 ft/second, which for pipe of this diameter would be in the turbulent region. Pressure drop would be 3.15 psi per mile based on the fluid having physical properties close to those of water. Data on pumping fibrous and thick (i.e., 7-10%) sewage sludges alone indicate that a friction loss 1.4 to 2.6 times that of water results[14]. However, sewage sludges are a minor component in the wasteline. The composition of the wasteline will have a much greater fluidity than that of sewage sludge mixtures, because of the presence of the large volume of colloidal solids in the dredge spoils. Conservative estimates would place the increase in friction loss for the wasteline mixture at approximately one and a half times that for water. This results in a pressure drop of 4.72 psi per mile. Total pressure loss for the 80 mile long undersea portion of the line would be 378 psi.

3.3 Future Waste Loads

As indicated in Section 3.2, long term, as well as short term, size stabilization occurs from having a component of relatively constant volume and major size in the line. Dredge spoils serve in the capacity in the wasteline.

The effects of future waste loads on line size will now be examined. Comprehensive projections for future sewage sludge volumes and industrial waste increases are avialable from data supplied in the Delaware Estuary Comprehensive Study[13]. These were developed on the basis of expected population and industrial growth increases and expected capacity and efficiencies of planned Regional treatment plants. Although the forecasts were made on the basis of COD loads, (i.e., carbonaceous oxygen demand, lbs/day) it can be expected that other waste indicators (e.g., BOD, UOD, suspended solids, etc.) would increase at about the same rate.

Figure 1 illustrates the anticipated increases in municipal and industrial wastes in the Delaware River Basin from the DECS report[13]. Applying these increases to the volume of industrial and sewage wastes found in 1970 as reported in Table 2 and taking account of the reduction in dredge spoils which will result as industrial and sanitary waste inputs to the River are reduced gives the projections tabulated in Table 3.

Table 3
REGIONAL FORECAST FOR CONCENTRATED WASTES
(million gallons per year)

	1970	1980	1990	2000
1. Dredge Spoils	1,414	1,164	1,164	1,164
2. Sewage Sludges	337	710	995	1,072
3. Waste Acids and Chemicals	340	755	1,240	1,740
4. Ashes (as 3% suspension)	18	18	18	18
TOTAL VOLUME	2,109	2,647	3.417	3.994

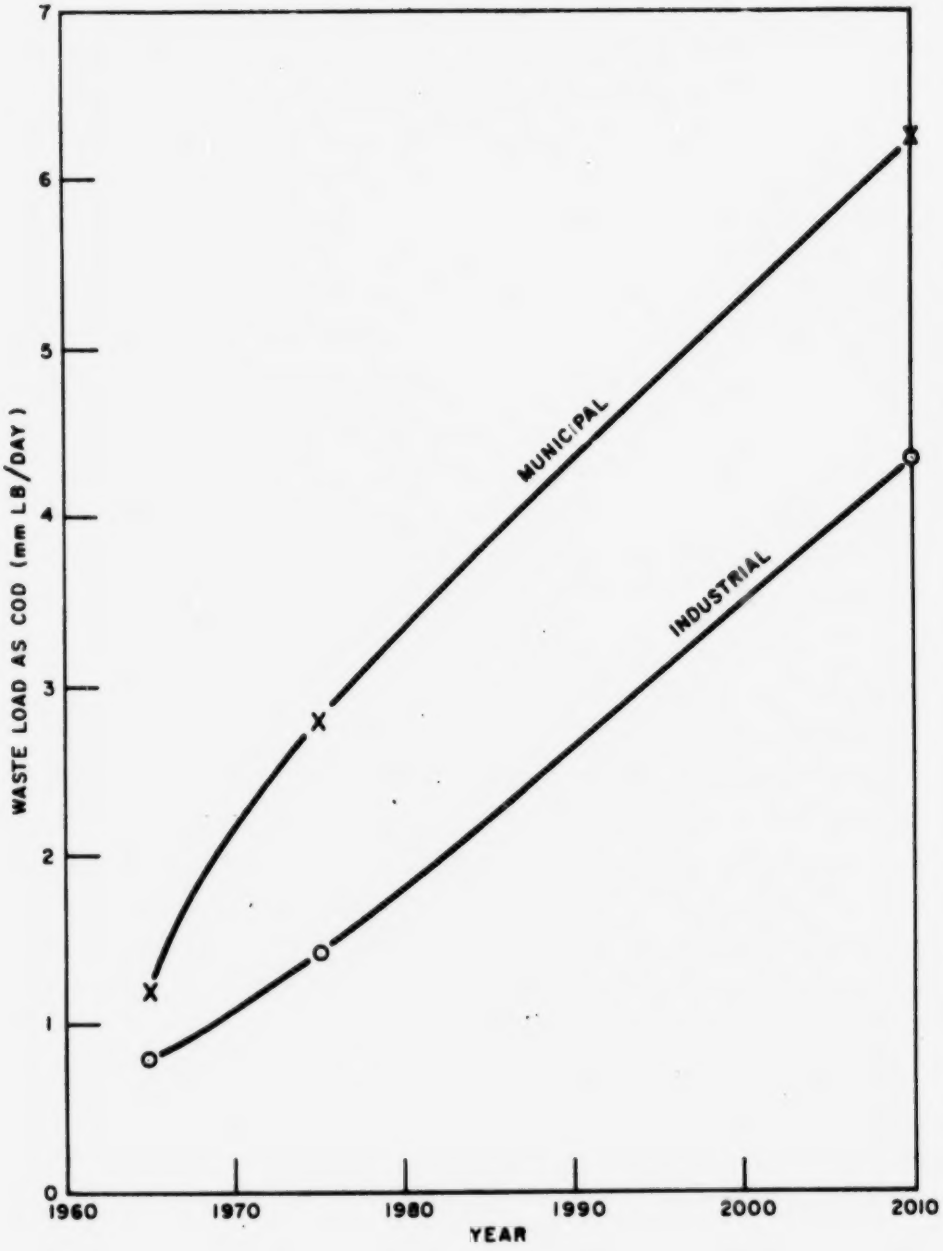

Fig. 1. Industrial and Municipal Waste Forecast for The Delaware River Basin (From DECS Ref. 13)

The discharge of industrial and sanitary wastes respectively account for 15% and 11% of the river's annual precipitated sediment load according to FWQA studies[4]. While a complete 26% reduction in shoaling may not be realized, even if the stricter DRBC discharge allocations are met by industry and municipalities, it should be possible to achieve at least a 15-20% reduction in spoils. A 17.5% spoil reduction is used in Table 4. This would greatly reduce the amount of solids put into the wasteline since the solids content of the spoils is so high (viz. 40%). This would add substantial volume capacity to the line.

Table 4 and Figure 2 illustrates this fact and shows the projected overall wasteline concentration based on the fixed 16 mgd line design volume.

Table 4
SOLIDS CONTENT OF PROJECTED WASTE LOADS
(million lbs/year)

1.	Dredge Spoils	5,950	5,160	5,160	5,160
2.	Sewage Sludge	280	590	825	851
3.	Waste Acids and Chemicals	85	189	310	435
4.	Ash	5	5	5	5
	TOTAL SOLIDS	6,320	5,944	6,300	6,581
	Wasteline Concentration (wt. % for 16 mgd flow)	12.3%	8.7%	12.2%	12.5%
	Dilute Waste Diluent Required to maintain 16 mgd flow (million gallons/year)	3,731	3,193	2,423	1,846

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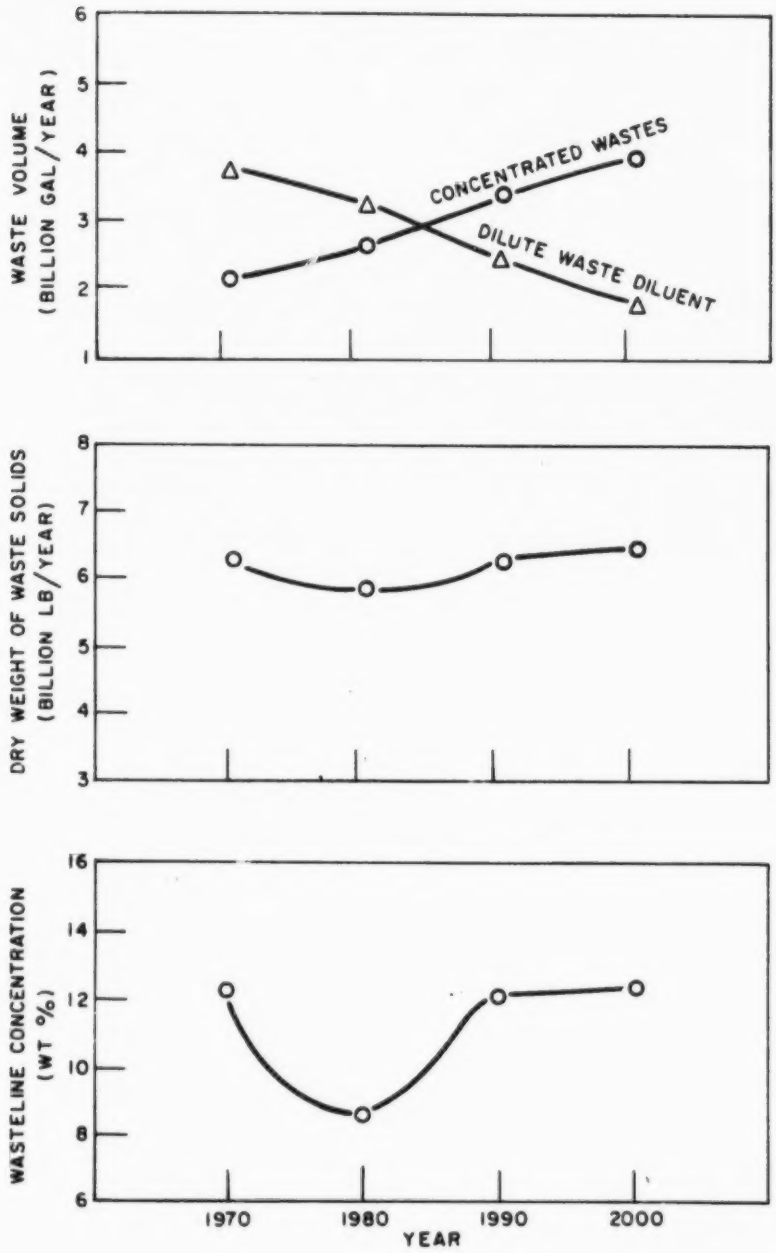

Fig. 2. Summary of Projected Waste Loads

3.4 Dredge Spoils

Dredge spoils are by far the most voluminous source of concentrated, unusable, waterborne wastes existing in the Delaware River Valley. Whereas the problem exists in many other regions the uniqueness and magnitude of the problem here is explained quite simply once it is recognized that Philadelphia, the nation's fifth largest port, is 80 miles up river from the ocean and depends on a man-made 40 foot deep by 400 to 1,000 foot wide channel for its operation. In comparison, New York and Norfolk which rank next but well below Philadelphia in spoil volume for the North Atlantic Region (viz. each with less than one-third of the Philadelphia spoil volume) are situated only 10-20 miles from the ocean and have deeper natural channels to begin with. (See Table 5). The natural average depth of the Delaware River is only 18 feet[4]. The dredge spoil volumes for the entire New England and Baltimore Regions which are also in the North Atlantic District are considerably smaller.

Table 5

ANNUAL DREDGE SPOIL VOLUMES NORTH ATLANTIC REGION[1,2]

	Cubic yds/yr
Philadelphia*	12,500,000
Norfolk	4,200,000
New York	3,100,000
New England (Conn., R.I., Mass.)	1,200,000
Baltimore	1,100,000
TOTAL	22,100,000

*Includes all tributaries of the Delaware River

Principal problems associated with dredge spoil disposal in the Philadelphia District are the small remaining capacity of spoil grounds and the opposition to the use of estuarine lands as spoil grounds when these lands had better be preserved for ecological or other reasons.

Estimates indicate that existing spoil grounds will be filled within 15 years. Recent attempts to sell settled dredge spoils found that there were no buyers.[5] While small quantities of spoils may be useful as a conditioner for sandy soils, the amount needed is just a small fraction of the total amount that is available annually.

The major shoaling areas in the Delaware River exist between Wilmington, Delaware and the Ben Franklin Bridge in Philadelphia a distance of some 20 miles (See Figure 3). The prime shoal area is at Marcus Hook, Pennsylvania an area of heavy industrial effluent discharge slightly above the normal salt water intrusion point at Claymont, Delaware. Approximately 7 million cubic yards per year (1.414 billion gallons) are dredged from this region.

From discussions with Mr. Lewis Caccese, Chief, Operations Division, Philadelphia District Corps of Engineers, he recommended that pipeline removal of the silty spoils from this principal shoaling area be given consideration. The smaller and geographically distributed volume of spoils from other section of the River might not be easily transportable by pipeline because of a high rock and sand content.

Long range planning studies by the Corps of Engineers on the transport of spoils by pipeline to remote spoil grounds accumulated considerable experience and information on spoil handling.[3] Analysis of these data revealed that with minor modifications dredge spoils could probably be mixed and pumped along with other concentrated waterborne wastes to the continental slope area.

The first modification necessary for accommodating dredge spoils in the pipeline would be dilution. Studies found that a two fold dilution

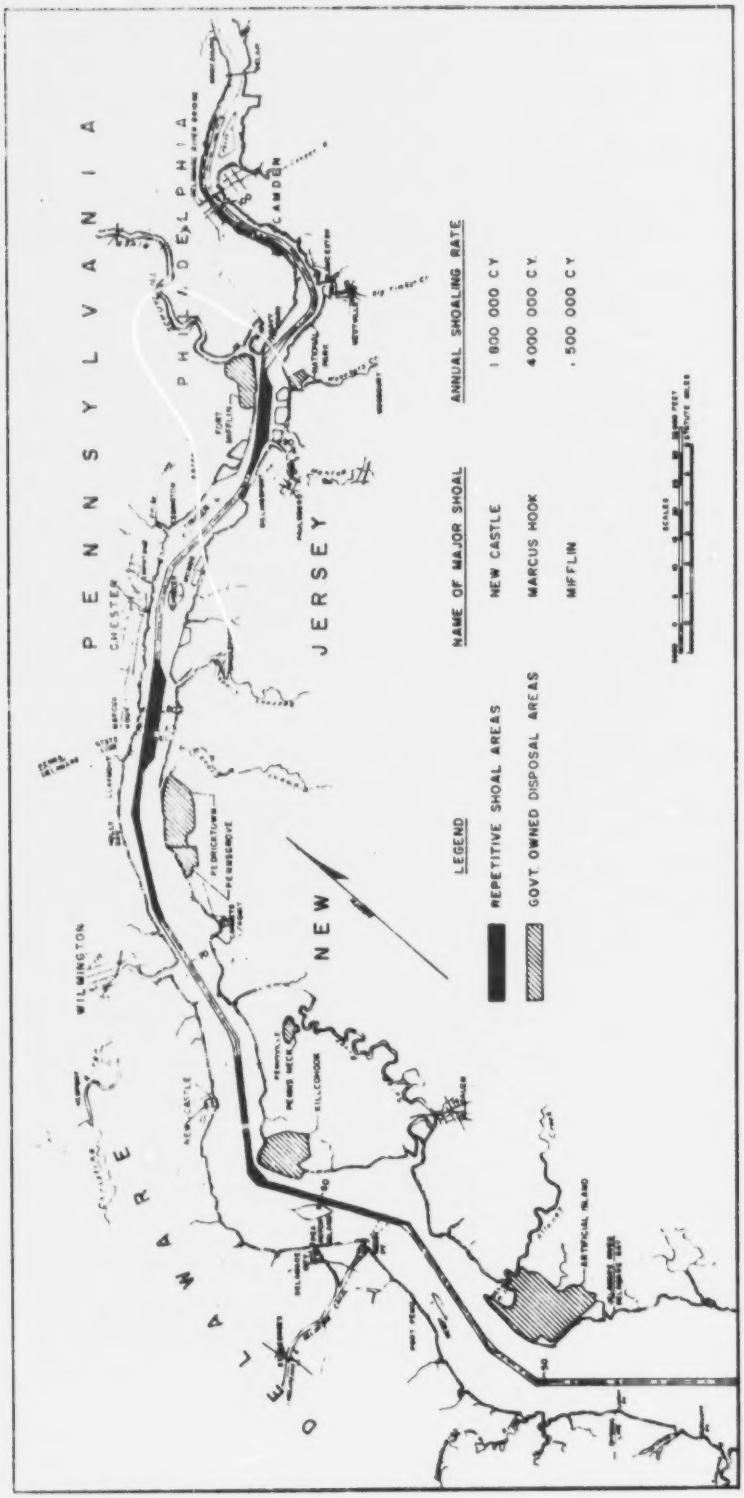

Fig. 3. Major Shoals in Delaware River (Ref. 3)

which reduced solids content from approximately 42% to 20% was satisfactory.[3] The second requirement would be the removal of sand and gravel from the spoils. According to Mr. Caccese these materials only constitute 5% of the solids in the spoils from the Marcus Hook Shoal. The remaining 95% of the solids are largely clays and have a mean particle size of only 1.6 micron. This creates a serious settling problem in spoil ground[5], but is a definite advantage in pipeline transport. Removal of the sand and gravel is essential in order to reduce the flow velocity necessary to maintain particles in suspension. It would also significantly reduce pipeline wear. By removing the coarse components in a settling basin at the input to the wasteline the 2 ft/second line velocity which results from a 36" pipe handling a flow of 16" mgd should be adequate to maintain the remaining fine particles in suspension with little difficulty. The Corps found that velocities of 9-12 ft/second were required in a 28" line if sand, gravel, and stones were not removed. This velocity was even sufficient to transport 2-1/2 inch stones which were present in the spoils.

It is quite conceivable that there would be a market for the 162,000 tons/year of sand and gravel removed from the spoils in the construction industry even though there was no market found for whole dredge spoils which included the high quantity of fines. While some fines are suitable as a component in soil, too high a fraction can completely plug soil drainage.

By removing the 5% sand and gravel component in the spoils the solids content would be reduced from 42% to 40%. The total fluid volume would remain unchanged at 1.414 billion gallons per year.

According to Mr. Caccese, the Corps of Engineers would presently pay a minimum of $0.20/cu. yd. for the permanent removal of spoils from the Region. This amounts to $1.4 million per year. There is a chance that they would pay $.25-$.50/cu.yd. in the future as spoil grounds become filled.

Knowledge of some of the composition and physical-chemical properties of dredge spoils are essential for system design and prediction of effects in the pipeline and in the ocean environment. A summary of some of these properties is given here.[1]

Concentration:	42 weight %
Density:	1.27 gm/cc
Solids Density:	2.3 gm/cc
Median Particle Diameter:	1.6 microns
Cation Exchange Capacity:	25.5 me/100

Rheological studies have been made on dredge spoils at The Franklin Institute Research Laboratories in recent years.[7,8]

Spoil density data as a function of solids content are plotted in Figure 4. These data were calculated from data supplied in reference 1.

It can be expected that the density-solids content relationship for the wasteline would be closely represented by the relationship in Figure 4 since spoils are such a significant fraction of the system.

The composition of the solids is the spoils is approximately[4]:

Organic Matter	9%
Clay	33
Non-clay Minerals	58
	100%

The organic fraction consists of about 50% coal dust which washes down from northern tributaries of the Delaware River. The rest is natural detritus and organic matter from sanitary waste discharges.

Principal clay minerals are illite, chlorite, kaolinite, and montmorillonite. Non-clay minerals are quartz and feldspar.

No significant amount of deleterious industrial materials, such as oils and metals (Pb, Cr and Cu) have been found in the Delaware River spoils as have been experienced with spoils from New York Harbor[9]. The

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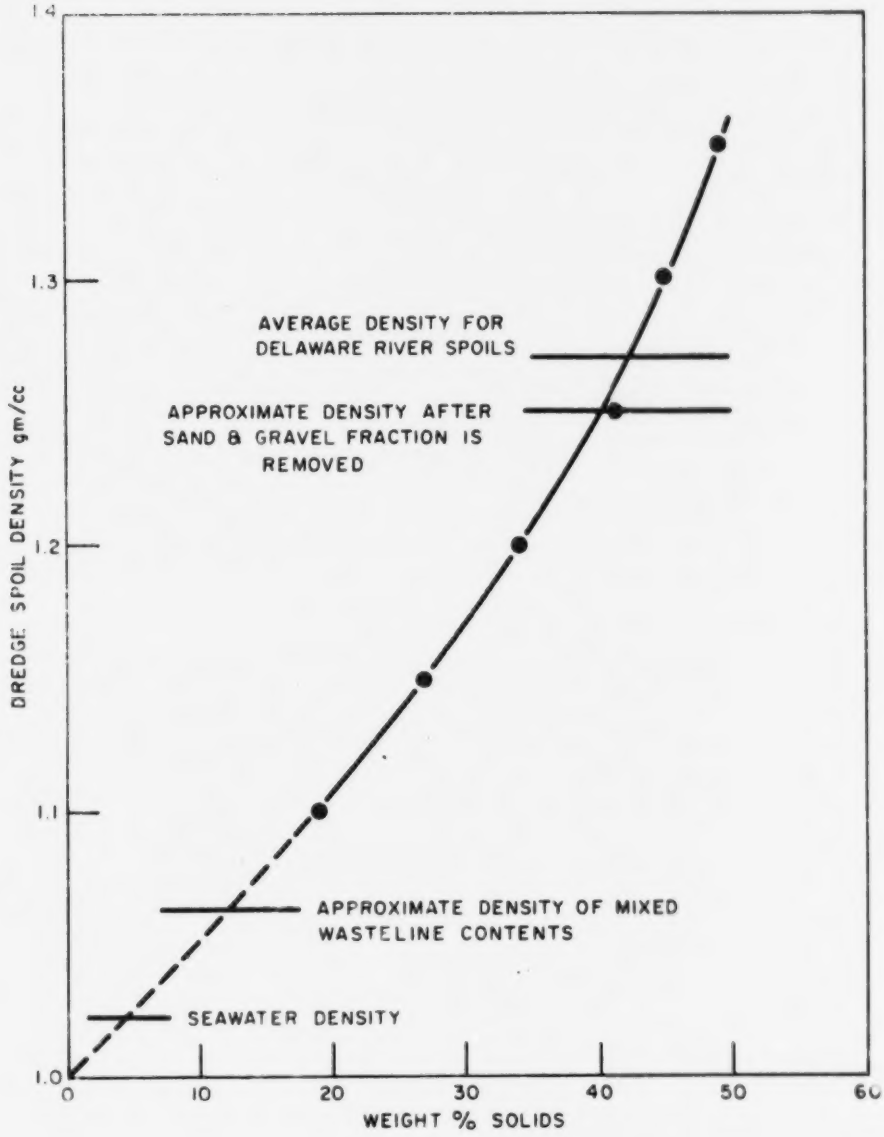

Fig. 4. Dredge Spoil Density as a Function of Solids Content (From Data p. 18a, Ref. 1)

major fraction of the sediments in the Delaware River are carried out to sea by the river. U.S. Geological Survey reports indicate that approximately 90% of the River's sediment load of 13 million pounds per day presently reaches the sea.[10]

From an examination of these basic data on spoils, it can be anticipated that a considerable amount of adsorption of industrial organic waste inputs can be expected on the large available spoil surface. In addition, ion-exchange activity can be expected to occur between certain inorganic industrial waste inputs and the clay components of the spoils.

Pending additional study, it would appear that dredge spoils from the Delaware River would not be an unnatural component of sea water and would not be expected to create ecological disturbances at a deep ocean outfall site when dispersed. In addition, admixture of industrial wastes with spoils would potentially neutralize and pre-dilute the reactivity of many of these inputs, which otherwise would reach the sea in unmixed and highly concentrated form, as commonly occurs from barging.

3.5 Sewage and Raw Water Sediments and Coagulants

A major fraction of the sewage sludges produced in the Region are already disposed of at sea. The City of Philadelphia which generates approximately 70% of the present 132 million gallon per year volume of the Region has had its sludges barged to a point 14 miles from the mouth of Delaware Bay since 1961.

Camden and Bridgeton*, New Jersey have also begun barging their sludges, making the total fraction of barged sludge approximately 83% of the Regions total volume.

The City of Wilmington, Delaware, the only other existing major sewage sludge source in the Region with approximatley 7% of the Region's present load, is currently using available ground disposal sites.

*Bridgeton halted dumping in January of 1971.

Three major changes will occur in the sewage sludge picture within the next few years. These changes will approximately double the amount of sludge to be disposed of. They are:

1. Construction of the Deepwater, New Jersey Regional Treatment Plant,
2. Construction of the Marcus Hook, Pennsylvania Regional Treatment Plant and
3. The Disposal of Sewage Sludge from Baltimore, Maryland off the mouth of Delaware Bay.

Table 6

Present Municipal Treatment Plant Sludge Volumes

System	Raw COD load (lb/day)	Sludge Volume* (m gy)
1. Philadelphia, Pennsylvania	1,020,000	93
2. Wilmington, Delaware	108,000	9
3. Camden, New Jersey	85,000	16
4. Darby Creek SA, Pennsylvania	37,000	3
5. Chester, Pennsylvania	26,000	2.1
6. Central Delaware County Sa, Pennsylvania	25,000	2.0
7. Lower Bucks County, M.A., Pennsylvania	21,000	1.7
8. Trenton, New Jersey	20,000	1.6
9. Hamilton, New Jersey	13,000	1.0
10. Muckinipattus, Pennsylvania	13,000	1.0
11. Bridgeton, New Jersey	13,000	1.0
12. Pennsauken Township, New Jersey	11,000	0.9
Total	1,392,000	132.3

*Sludge concentration at 10 Weight %

Baltimore's sludge disposal must be considered in the present study, since its disposal is actively being planned in the study Region[11]. Its sludge up to now has been dried and disposed of as land fill. The volume of sludge from Baltimore will amount to approximatley 100 million gallons per year[11]. A study was made by the Bechtel Company for disposal

of the sewage sludge from both Baltimore and Washington, D.C.[12]. Ocean disposal would be carried out by pipeline with discharge beyond the shelf break.

Whereas inclusion of the Baltimore sludge volume in this present study appears necessary because of the imminent discharge of this material in the Delaware Estuary, it is beyond the scope of this present study's objectives to include wastes from other major Regional sources at this time.

Discharges from many industrial plants in the Region are being handled by municipal treatment systems. Guarino reports that 44% of the BOD load to Philadelphia's secondary treatment system is now industrial waste[15]. We would expect that the presence of a wasteline for the ultimate disposal of concentrated industrial wastes would decrease the loading on these systems. This would improve the operation of these systems and also partially reduce the volume of sewage sludges generated. The size of the reduction in sludge volume is difficult to estimate. The bulk of the industrial wastes are dilute and would not be taken directly by the wasteline. For purposes of accounting for this effect in the design of the wasteline, the sewage sludge volume for the Region will be arbitrarily reduced from 132 million gallons per year by 8 million gallons per year or by about 6% of the present total sludge volume. This puts the present sewage volume at approximately 124 million gallons per year.

Plans are underway for the construction of two 100 million gallon per day Regional treatment plants which will handle combined domestic and industrial wastes. One will treat wastes on the east side of the Delaware River with its location being about 20 miles south of Philadelphia at Deepwater, New Jersey. The other plant, designated as the Marcus Hook plant will probably be located about 10 miles south of Philadelphia at Marcus Hook, Pennsylvania on the more populous west side of

the Delaware River. The wasteload to each plant will be largely industrial input. Under support by the Delaware River Basin Commission and private industries, the Deepwater plant is well along in planning. Pilot plant studies of the anticipated waste loads have already been made. These indicate that 90% BOD removal would be possible[17]. The Marcus Hook study is not yet at this point.

As an estimate of the total sludge volume for both of these two plants, figures based on the actual operating experience of Philadelphia's treatment system can be used as a guide. Philadelphia's treatment system handles 447 million gallons per day of sewage. Its operating efficiency is currently ca. 60% based on BOD removed [16]. The sludge volume generated on this basis is currently 93 million gallons per year.

A 200 mgd combined treatment system operating at 90% BOD removal could be expected to generate 62.5 million gallons per year of sludge. Deducting ca. 6% of this value to account for sludge reduction, which could result from putting concentrated wastes directly into a wasteline systems gives a sludge volume of 58 million gallons per year.

Sediments and coagulants from fresh water treatment plants in Philadelphia are currently back flushed to lagoons. It is expected that this material will eventually be fed to the Philadelphia North East Sewage Treatment Plant, where it will be disposed of along with sewage sludge[18]. The volume of sediment and coagulants currently being generated is equivalent to 55 million gallons per year taken as a 10% suspension. This volume added to the 282 million gallons per year of sewage sludges gives a combimed total of 337 million gallons per year of municipal sludges.

3.6 Industrial Waste Concentrates

Establishing an accurate figure for the volume of chemical wastes which are available or would become available for ocean disposal proved to be one of the more difficult task in the waste survey. As

a result, estimates were made based on a total evaluation of the Regional waterborne waste situation, with strong reliance on the quantitative data available for currently barged chemical wastes.

As the logical starting point for locating industrial wastes appropriate for ocean disposal, a review was first made of the types and volumes of industrial and chemical wastes that are already being barged to sea from the Delaware River Basin.

Data were available for the period covering the entire past 12 year period from the Philadelphia District Office of the U.S. Army Corps of Engineers [19,20,21]. Tabulation of these data is made in Table 8. The first significant observation which can be made is that there has been surprisingly little ocean disposal of chemicals from the Region thus far, in comparison to other areas such as New York City. The recent study by Brown, Smith, and Gunnerson found that approximately 635 million gallons per year of waste chemicals and acids were being barged to sea from the New York area[23]. Table 7 shows that very little ocean disposal occurred from the Delaware river area until about 5 years ago. The annual volume of chemicals now regularly barged to sea from the area appears to be approximately 104 million gallons per year - about one-sixth that of the New York City area.

There appears to be two good reasons for this difference. First, there is a far greater availability and very extensive use of lagoon and land-fill areas in the less congested Delaware River Basin, than in the heavily built-up New York and Northern New Jersey area. Secondly, the cost of barging waste chemicals to sea is greater from the Delaware Basin than from the New York area, since the location of the majority of petroleum refineries, chemical, paper, and steel plants are located 80 to 100 miles up river from the mouth of Delaware Bay and the ocean.

Table 7
INDUSTRIAL WASTES BARGED TO SEA
FROM THE DELAWARE RIVER BASIN
IN THE PAST 12 YEARS (REF. 19-21)

Data	Source and Materials	Volume (gallons)
25 Nov 1958	Rohm & Haas Company, Dithane M-22 (agricultural fungicide)	165,000
17 Jan 1959	PSE & Gas Company, Sulfur Slurry	650,000
Dec, 1963	DuPont Company, Waste Acids	500,000
May-July 1965	Rohm & Haas, Saline Solutions	1,367,000
Year 1966	Rohm & Haas, Arsenical Solutions	5,500,000
Year 1967	Rohm & Haas, Arsenical Solutions	5,350,000
Mid 1968 to present	DuPont Company, Waste Acids (2 Trips/week, @ 1 mm gall each)	104,000,000/year

The practice of on-plant retention of wastes is probably the most significant reason for the lower present level of chemical disposal at sea in the Delaware River area. A recent Manufacturing Chemists' Association survey of wastes from 981 U.S. chemical firms revealed that indeed the major portion (Viz. 71%) of all wastes generated at chemical plants were disposed of as land-fill on company-owned property[24]. The breakdown of all disposal methods uncovered in that survey is shown in Table 8.

The description "waste solids" encompasses many materials which do not fall into the area of what might seem to be classified as waterborne wastes. However, much of the chemical waste going into landfill does have the potential of enventually creating water quality problems, and much of it originates as waterborne waste.

Table 8
DISPOSAL METHODS FOR WASTE SOLIDS FROM CHEMICAL PLANTS

	Tons Per Year	%
Land-Fill		
On Company property	8,067,000	71
Not on company property	520,00	5
Incineration		
With heat recovery	92,000	1
Without heat recovery	231,000	2
Open dump burning	109,000	1
Contracted Disposal	1,627,000	15
Other Or Unspecified	616,000	5
Total	11,262,000	100

The practices of land-filling and lagooning in the Region were confirmed in the interviews, which were held with major chemical, petroleum, paper and metals companies in the Region. It was concluded from these interviews that as long as fill capacity exists, no company would be very interested in using other means of disposal such as ocean disposal - except for exceptionally troublesome materials. The benefits of using land-fill disposal have been twofold. The first advantage has been the ease and inexpensiveness of the practice. The second has been the generation of useful land which results from the land-fill. However, there are signs that in the near future the picture may change, since pressures on the capacity of these practices are beginning to be felt. Discussions at the District Corps of Engineers indicated that within the past year there have been many new requests granted and facilities built for the future barging of chemical wastes from the Region[22].

It was learned from the interviews with representatives of the petroleum industry that it is common practice at most refineries to drum and toss troublesome refinery wastes, such as tarry and acidic oil residues, from the decks of ocean-going tankers. However, no estimate of the total volume of materials being disposed of in this manner was obtainable.

The direct interviews with private companies in the Region resulted in the obtainment of a good understanding of the Regional waterborne waste picture. However, definite data on the quantities of concentrated wastes which would be available from specific companies for a wasteline were not obtainable. Extreme caution and reluctance to admit to the generation or availability of waste concentrates was found in some interviews.

Data on the volume and concentration from all sources of industrial discharge in the Delaware Basin had been compiled during the extensive 1961-1966 Delaware Estuary Comprehensive Study conducted by the FWQA. A study of these detailed data at the Philadelphia FWQA Office was made. Table 9 illustrates some of these data on total solids discharged by the principal industrial dischargers in the Region. It can be seen that approximately 4 million pounds of total solids per day are generated by these principal dischargers. It was not reported and there is no way of accurately estimating what fraction of this 4 million pounds per day might be captured as concentrated waste. Even if only one or two percent of these waterborne solids were collected for direct ocean disposal by pipeline, a significant reduction on the loading of treatment plants and receiving waters could result (N.B., 1% of these solids is equivalent to 15 million pounds of solids per year).

Interviews and discussion with regulatory authorities, waste consultants, and manufacturers of equipment and chemicals used in the water and waste treatment fields indicated that a "considerable" but not

Table 9

1964 INDUSTRIAL WASTE LOADS

	Ind.	C.O.D. #/Day	Total Solids #/Day	Flow (MGD)	pH
Paper	Scott	22,175	39,596	13.435	5.3
	Mac Andrews & Forbes	30,957	26,804	4.354	5.8
	Ruberoid	21,802	19,258	.178	7.0
Chemical	Hercules	11,086	17,857	.282	7.7
	N.J. Zinc	4,146	411,197	5.44	4.6
	Monsanto	51,416	97,273	1.114	1.6
	DuPont Chambers Work	202,395	1,658,628	103.33	2.5
	Atlas	19,092	-45,486	10.1	6.4
	DuPont, Repauno	737	46,284	52.412	6.3
	Allied	7,856	707,253	33.30	3.1
	FMC	4,157	28,577	1.503	7.2
	DuPont Carneys Point	19,819	198,239	4.749	1.3
Oil	Atlantic	37,855	121,368	24.37	8.7
	Texaco	8,157	9,750	2.50	8.4
	Gulf	26,302	60,513	11.129	8.6
	Mobil	51,267	133,710	34.63	7.0
	Sinclair	8,900	18,942	59.38	7.1
	Sun	59,918	-34,683	110.94	7.2
	Tidewater	6,486	59,257	278.6	7.4
Metals	U.S. Steel	2,868	105,880	73.984	7.8
	Total:		3,680,000	823.000	

readily ascertainable volume and variety of concentrated wastes were being generated in the Region. Existing sewer systems, private lagoons and burial grounds, as well as direct discharge to waterways now receive the bulk of these materials.

The data on presently barged chemicals were utilized as the basis for estimating the volume, concentration, and composition of Regional industrial wastes, which might now be totally available for an ocean wasteline.

If it were assumed that the exisiting practices of private landfill and lagooning in the area were to reach their capacity, the volume of waste chemicals which would become available for "ultimate disposal" would certainly be expected to reach some multiple of the present 104 million gallon per year rate. A sixfold increase to the level experienced in the New York - Northern New Jersey area might be attainable. However, as a conservative estimate for design purposes of the wasteline, it was decided that about half of the New York area volume or approximately a threefold increase of the known volume of wastes presently being disposed of at sea in the Delaware Region would be used. This figure was rounded to 340 million gallons per year, making it about equivalent to the present volume of sewage sludges in the Region.

The concentration of the industrial waste chemicals could be expected to range from 100% pure non-aqueous organic or inorganic materials, such as filter-cake residues, to 1-2% reasonalby dilute aqueous solutions of caustic, acid or salt solution. Since most industrial sources interviewed emphasized the strong desirability of not having to partially concentrate any waste to make it more handlable by a waste collection systems, a reasonably dilute value of 3% solids (95% water) was picked to represent the concentration for the total industrial waste input.

It should be noted that considerable variation in the quantity and concentration of industrial waste input would not seriously affect

the design of the wasteline system. The presence of the huge volume of spoils and dilute industrial wastes would compensate for as much as a 100% variation in the estimates of industrial waste volume and concentration.

The types of industrial chemicals which can be expected to be available for a wasteline would be predominantly acid wastes, judging from the data on what has been barged from both the Delaware River Basin and the New York City areas. The chemical nature of the wastes would also appear to be almost totally inorganic in character. The small amount of organic wastes which would be present (e.g. dyes, solvents, pretroleum chemicals, etc.) would be an even smaller fraction of the total line volume. No evidence of wastes from the manufacture of chemically stable and long lived pesticides such as the chlorinated hydrocarbon variety (viz. DDT, DDE, TDE, etc.), were found in the Region. In addition, no significant quantities of oils or other floatables were found. Waste heat recovery burners are commonly used at petroleum refineries where such wastes would be expected.

Mixing and pre-dilution of the industrial wastes in the line, along with the long 100 hour hold time in the line prior to release at the outfall site could assist in reducing any initial shocks that the industrial components in the effluent might have on the ocean environment.

3.7 Ashes

Waste ash in the Region was analyzed as a potential source of materials for the wasteline. In particular, as was sought which was creating a water pollution or disposal problem and which was fine enough to be easily transported as a slurry be pipeline.

The biggest source of waste ash until two years ago was fly ash produc as the top ash from the combustion of coal. However, it has now

almost completely disappeared from the Region as a result of power companies switching to low sulfur fuel oil, in order to comply with air quality regulations.

As an indication of the rapidity and extent of the changeover Philadelphia Electric Company, the major power company in the area which in 1968 had eight of its power stations in the Philadelphia Region burning coal, now in 1970 has seven of the eight stations using low sulfur oil. The rapidity of conversion does not represent a great technical effort, since most power stations are already equipped to burn dumped gas during the summer off season as well as coal.

The Delaware Power and Light Company which serves the metropolitan areas south of Philadelphia has announced plans to convert its two largest power stations (one at Wilmington, Delaware, the other at Vienna, Maryland) to low sulfur oil [25].

Atlantic City Electric Company, on the New Jersey side of the Delaware River has already converted its plants to oil.

Large nuclear power plants are under construction in the Region for future use. Consequently, it can be safely concluded that disposal of excess fly ash should not be a future problem in the Region.

The potential employment of sulfur dioxide neutralization or recovery processes to permit the burning of high sulfur coal appears to be a highly remote possibility at this time.

The introduction of such processes could solve the air pollution problem of high sulfur coal usage but would introduce new and very costly water and solid waste pollution and disposal problem. From interviews with representatives of the Philadelphia Electric Company the general concensus is that commercially useful processes do not yet exist [27,28]. Solid waste disposal and raw material handling and storage costs are the biggest present drawbacks. If entirely new processes were developed in

the future for on-site sulfur removal at power stations, it could be expected that large amounts of waste slurries would be generated. Disposal of these slurries by a pipeline to the deep ocean would have to be reconsidered at that time, as well as the associated problem of excess fly ash disposal.

The combustion of oil at power stations produces some top ash but on a very much smaller scale than that from coal combustion. Disposal of this small volume of ash is not a problem at present.

Incinerator top-ash, from the seventeen municipal refuse burning stations in and around Philadelphia, is produced at a rate of about 15-20 tons/day or ca. 12,800,000 lbs./yr.[26]. These fine top ashes are currently disposed with the vast bulk of bottom ashes produced. Consequently they are currently not a problem.

Chemical incineration at refineries and industrial plants in the Region (e.g. incinerated A.P.I. separator sludges, incinerated spent catalyst plus other oil or solvent rich sludges) produce a volume of heterogeneous ash residues which might be more appropriate for deep sea disposal than the land-fill or near-shore ocean dumping methods that are now used. Information on the volume of such ash residues is not readily available since significant landfill capacity undoubtedly still exists on private grounds for these waste materials.

It appeared that some provision for waste ash slurry should be included in the wasteline inventory even though no firm input of ash residue was located. In view of the extensive use which has been and will be made of incineration in the waste management field and because of the wide spectrum of residual ash compositions that result, provisions for its inclusion appears appropriate.

Most top-ash generally consists of oxides of aluminum, magnesium, silicon and iron plus some carbon. However, the wide variety and unconstant composition and character of ash sources are a drawback to

to finding applications for these materials. Therefore, it is expected that at sometime in the future, when land disposal is no longer available, there will be a supply of heterogeneous ash residues available for ocean disposal.

An ash allocation of five million pounds per year has been selected for inclusion in the top-ash volume produced at all of the municipal incinerators in the Region.

4. ROUTES

A total of five alternative routes have been examined for the Wasteline. Four of these were existing rights of way and were parallel to each other between Philadelphia, Pa. and Atlantic City, N.J. (see Figure 5). These were:

1. The rail path of the Pennsylvania and Reading line,
2. the Atlantic City expressway,
3. electric transmission lines of the Atlantic City Electric Company, and
4. gas transmission lines of the New Jersey Natural Gas Co.

Portions of each of these several rights of way would probably to utilized.

A fifth alternative considered was a totally submarine line down the Delaware River and Bay. The latter has been tentatively rejected because of the much greater length of the river route and the greater distance from the mouth of the Delaware Bay to the shelf-break.

The outstanding advantage pointed out for this all water route was that of way could be established without involving private owners (29).

However, no right of way conflict appears to exist in any of the other four routes considered. Corridors for transportation and utility lines already exist between Philadelphia and Atlantic City. Multiple use of rights of way between two or more public services will require less land consumption.

A logical and practical pick-up point would be at an existing spoil ground. The Government owned spoil ground at National Park, New Jersey (see Figure 2), located on the Delaware River and Woodbury Creek, just south of the Philadelphia - Camden area on the New Jersey side of the river, appeared as an appropriate choice.

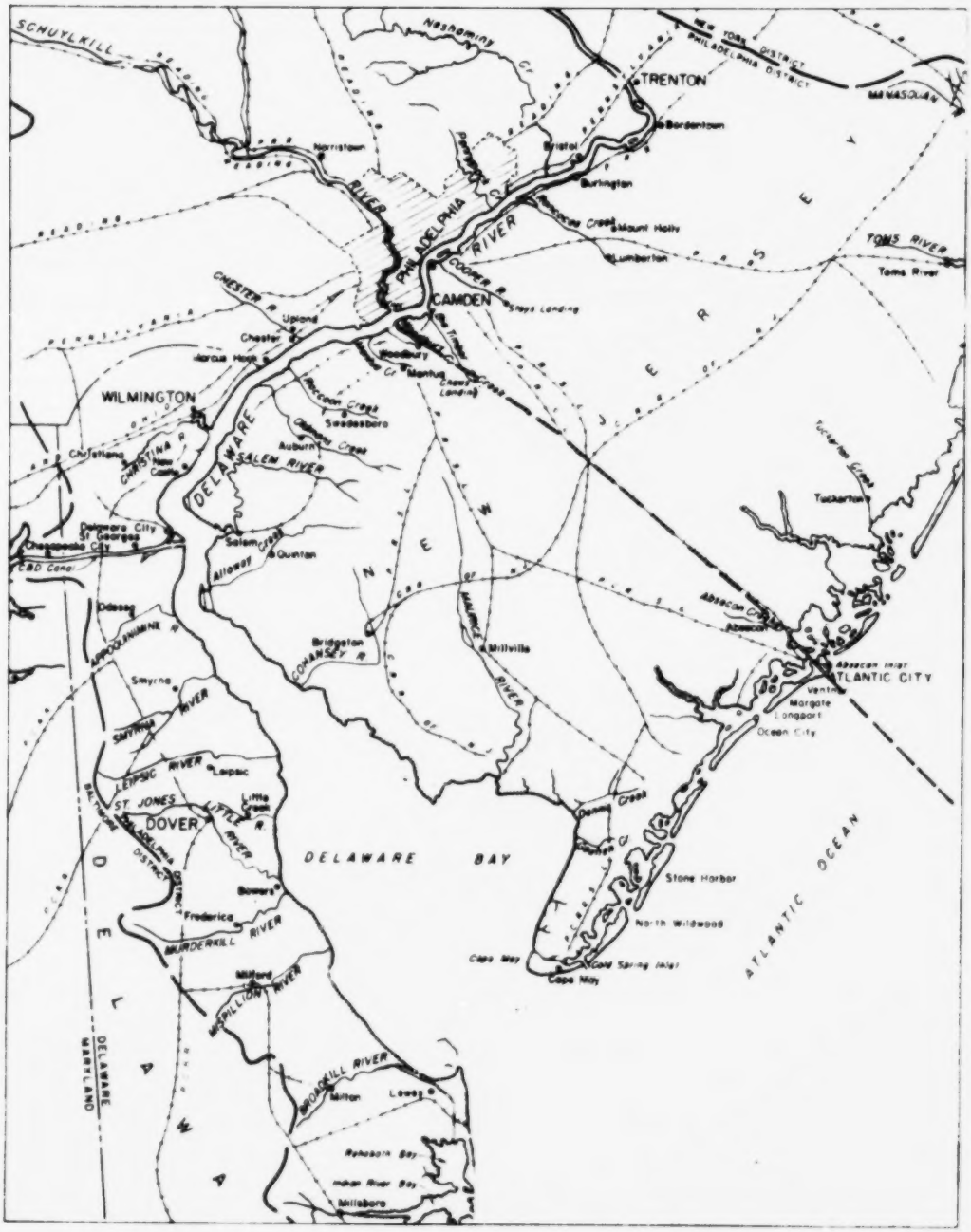

Fig. 5. Pipeline Land Route
(Ref. 1)

Discussion with Mr. Lewis Caccese, Chief, Operations Division, Philadelphia District, U.S. Army Corps of Engineers, indicated that it should be possible to use an existing spoil ground to impound other waste materials prior to their controlled addition along with dredge spoils to the wasteline (5). Storage tanks for some ingredients of the line which require controlled slow addition over a long period of time could also be built at the spoil area.

Two to three pumping stations would be used along the sixty mile overland right of way. This would divide and reduce the 283 psi pressure drop to a level which would allow the use of less expensive and more corrosion resistant non-metallic piping.

At the shore there would be a final pumping station for pumping the mixed wate through the 80 mile long undersea leg.

A two day transit time would elapse for the trip between National Park and Atlantic City, N.J. There would be adequate time to monitor the behavior of various inputs to the line during this two day transit so that adjustments or neutralizations could be made if necessary, prior to forwarding the waste load through the undersea leg.

In order to tolerate the 378 psi in the pipeline section immediately downstream from the shoreside pump, a section of lined steel pipe, or heavily reinforced plastic pipe would be used. As pressure drop occurs along the undersea pipeline path, lower rated plastic pipe would become the material of construction.

The pipe will be buried over most of the continental shelf bottom because of the heavy amount of trawling which occurs in the relatively shallow 200 foot shelf waters (see Figure 6 for map of undersea route). Near the shelf break and on the upper slope region at depths of 600 to 1,200 feet, the line may not require burial because of sparser marine activity. However, some lobster trawling does occur at this location

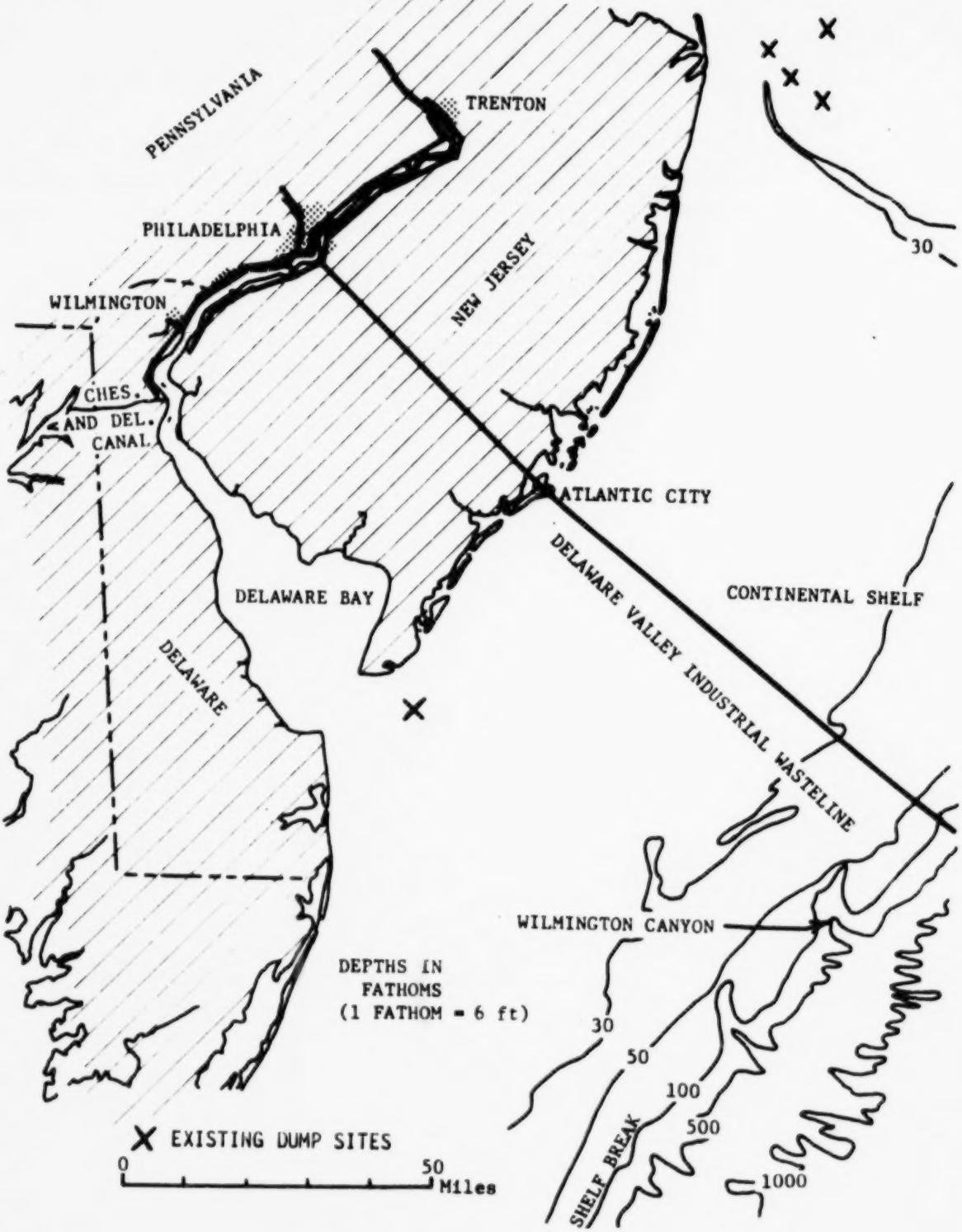

Fig. 6. Overall Pipeline Route

and will be further considered for its effects on a submarine pipeline. Burial would be carried out by hydrojetting sand from beneath the line.

Diffusion ports along the last section would probably be used to assist in achieving more effective dispersal.

5. PIPING

The importance of selecting the right pipeline material(s) cannot be overemphasized. The major cost in this system would be for the pipe itself and its laying.

An intensive study was made during the past year on potential pipeline materials and pipe laying methods.

The entire basis for the selection of proper pipe material hinged on the determination of the physical and chemical composition and flow rate and volume of the wastes.

The most important preliminary bit of information required was the chemical nature of the wasteload. Although abundant data on the effects of various substances on pipe material were available from manufacturers' tests, it was recognized that realistic long-term evaluations would be required for any pipe material that might eventually be selected for actual use. No experimental tests on pipe materials were started until the survey on waste sources was completed, since only data on an accurate representative waste mixture would serve the purpose of this study.

Whereas static immersion of pipe test pieces ordinarily would suffice to obtain corrosion behavior, some form of a more realistic test under strained conditions simulating actual use conditions was essential for the plastic materials being studied. Environmental stress corrosion cracking is a common phenomena with polymeric materials. A review of established ASTM tests followed by an examination of a large pipe testing facility at the Johns-Manville, N.J. were made to aid in the selection of appropriate test procedures. It was evident that at this point of the study what was actually required was a screening test for eliminating all unfavorable materials from future considerations. The environmental

strain cracking test racks shown in Figure 7 were developed at The Franklin Institute Research Laboratories for simultaneously screening large numbers of plastic piping materials while under strain and while immersed in a mixture whose composition closely approximated that of the actual wasteline. Tensile strains of 0.5% and 1.5% are being applied to the specimens being tested. As yet there are no results, which would either eliminate or tend to favor any of the materials being studied. Table 10 gives a list of materials being tested.

Table 10
PLASTIC PIPE MATERIALS EVALUATED

Material	Manufacturer-Distributor
High Density Polyethylene	Aldyl D, DuPont Co.
	Driscopipe 7000 M, Phillips Petroleum Co.
	Hostalen GM 5010, Ecologic Resources Inc.
High Density Polybutylene	Resin PB 200 Mobil Chemical Co.

The materials listed in Table 10 are representative of the most suitable polymeric materials available. Polyvinyl chloride was not chosen for actual testing, because of its significantly poorer long term stability. Slight cost advantages in resin prices become insignificant in comparison with the price of extrusion and long term product intergrity. Missing from the listing are polyester resings such as those used in polyester-glass reinforced pipe (Flextran, Rigidon, etc.). This classification of pipe has some potential for use in the overland leg of the system. The importance of having polyester materials in the test program was emphasized to manufacturers of reinforced pipe. However, to date no samples have been received.

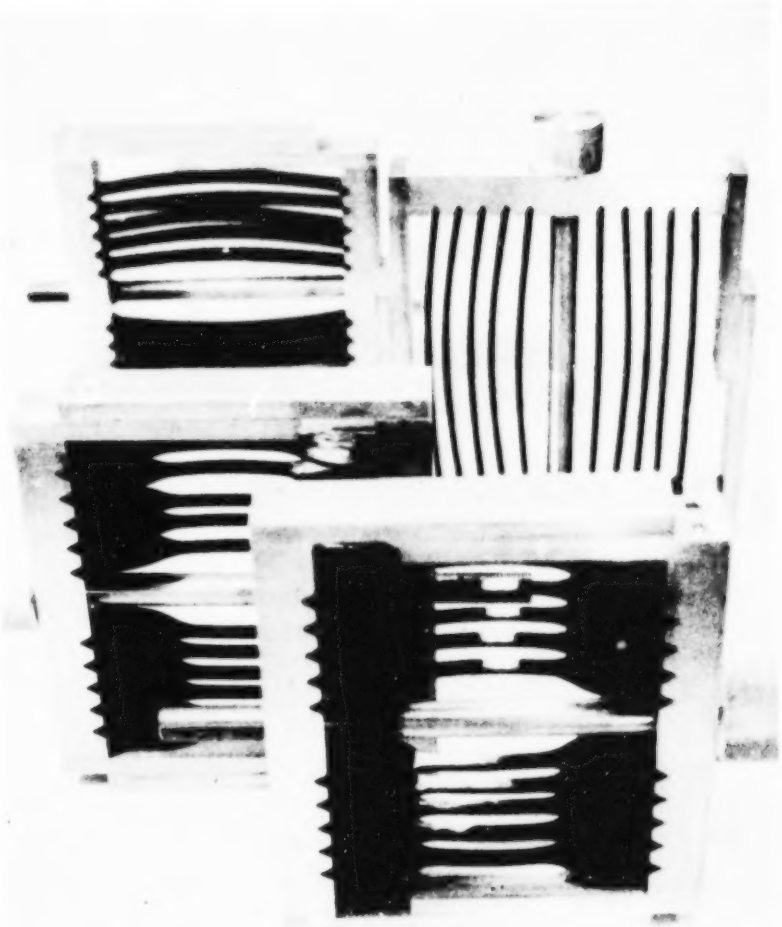

Fig. 7. Racks With Specimens For Environmental Strain Cracking Tests.

6. BASIC ASPECTS OF DISPOSAL ON THE UPPER CONTINENATAL SLOPE

The major objective of this report has been to cover in some detail work done in the principal study areas of this year's program. The engineering studies (i.e., waste inventory and system sizing) and ocean studies were the two major areas of concentration.

The ocean studies commanded far more time, manpower and interest than the engineering design aspects and in the long run should be the most significant aspect of this work. However, the ocean studies cannot,in fairness to their importance, be adequately covered in this report. Whereas it was possible to interpret a good part of the work on the engineering aspects for this report, a major and significantly important segment of the oceanographic work requires more qualitative than quantitative evaluation.

A baseline study on the chemistry and biology of the upper slope region surrounding the coordinates of 73° 10' West, 38° 33' North was undertaken. Data on the species and the relationship between biological communities present were essential for purposes of evaluating ahead of time what effects the release of wastes might have on the immediate region and upon the surrounding ocean in general. Hydrographic and geological measurements were also an important part of the baseline study. Information on current speed, direction and ultimate destination were needed. A detailed knowledge of the depths and contours of the upper slope bottom in the region of interest was also desired, in order to help correlate hydrographic and biological data and for pipelaying considerations.

Figure 8 is a chart of area studied with station indicated.

Table 11 reviews the major categories of ocean measurements conducted in this year's program. Table 12 shows the oceanographic cruises on which these experiments were carried out.

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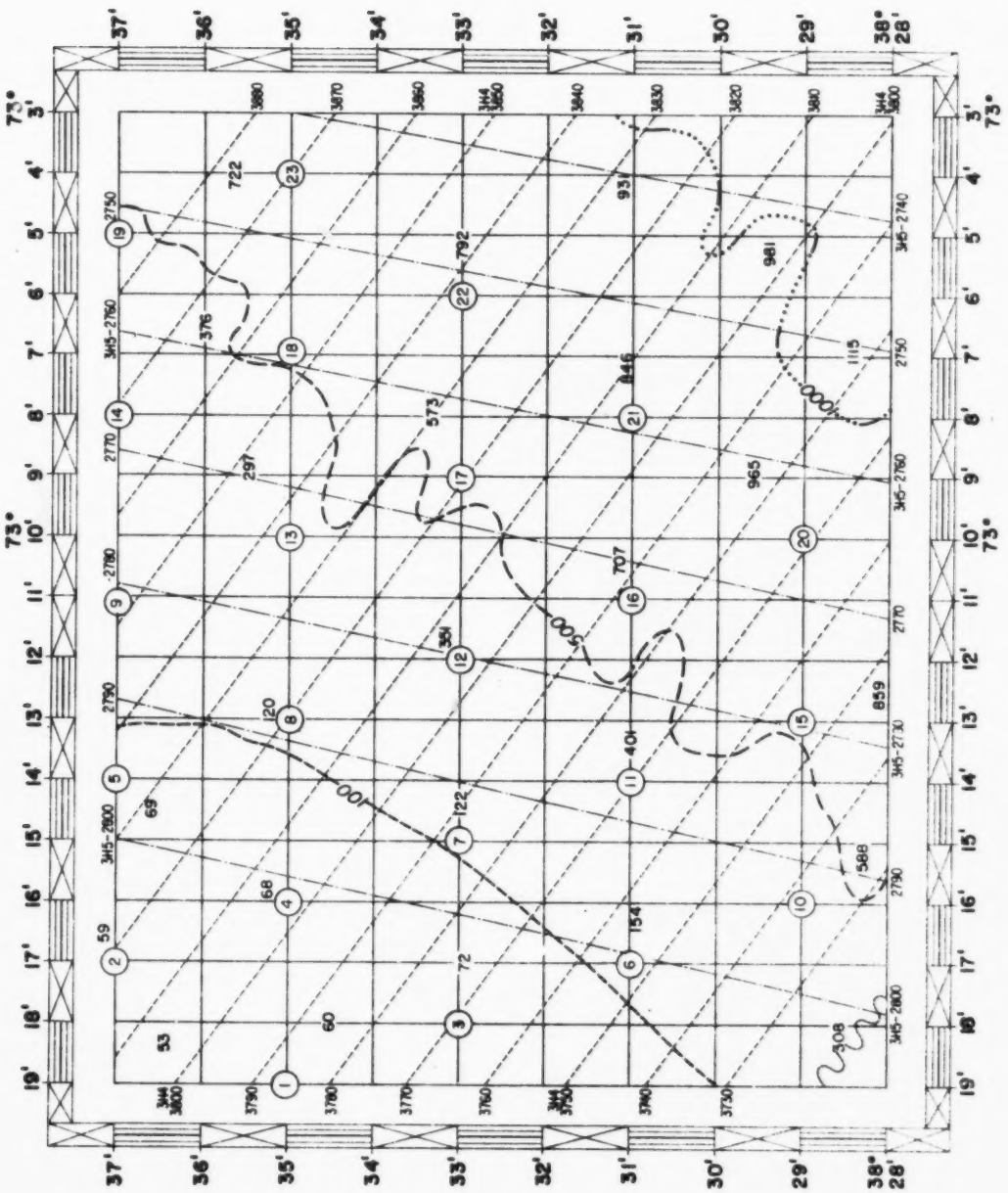

Fig. 8. Locations of Data Stations - Continental Slope Survey

Table 11

SUMMARY OF OCEAN MEASUREMENTS

Data Category		Measurements	Water Depth
6.1	Chemical	1. Dissolved oxygen content	Surface and bottom
		2. Salinity	Surface and bottom
6.2	Biological	1. Trawls for fin and shellfish	Bottom on slope and at shelfbreak
		2. Benthic samples with Smith-McIntyre Grab	Bottom on slope and at shelfbreak (SHML)
		3. Plankton nettings	Surface and bottom slope and shelfbreak
6.3	Hydrographical	1. Current speed and direction by current meter	Bottom on slope and at shelfbreak
		2. Current destination by seabed and bottom drifters	Released at slope and shelfbreak
		3. Temperature by Spilhaus bathythermongraph	
6.4	Geological	1. Direct observations - by research submersible "Ben Franklin"	On upper slope and shelfbreak
		2. Bottom contour and depth by fathometer	On upper slope and shelfbreak
		3. Sediment sampled - by Smith-McIntyre Grab and Saunders Anchor dredge	On upper slope and shelfbreak (SHML)

SHML - Indicates data taken by Sandy Hook Marine Laboratory

Table 12

SUMMARY OF OCEANOGRAPHIC CRUISES TO STUDY REGION

Cruise No.	Vessel Port	Date	Principal Objectives
1.	"Doris Mae III" Barnegat Light, New Jersey	10-11 August 1969	Deploy marker buoy and seabed and surface drifters
2.	"Privateer"/ "Ben Franklin" Atlantic City, New Jersey	7-10 Sept. 1969	Direct observation and photographic recording of biological and geographical conditions at slope regions and observe and photograph release of samples of various representative wastes
3.	"Capt. Deebold" Atlantic City, New Jersey	29-30 Oct. 1969	To emplace two current meters and deploy seabed and surface drifters
4.	"Capt. Deebold" Atlantic City, New Jersey	23-24	To recover current meters, deploy seabed and surface drifters and obtain bottom grab samples
5.	USCGC "Rockaway" Governor's Island New York	1-7 Dec 1969	To act as observer and obtain chemical, hydrographical, and geological data gathered on the cruise and to locate and recover current meters deployed on Cruise No. 3
6.	R/V "Dolphin"	18-20 May 1970	Chemical water analyses, current and water temperature measurements, fish and benthic organism samples; sediment samples
7.	R/V "Dolphin"	1-4 June 1970	Chemical water analyses, current and water temperature measurements, fish and benthic organism samples; sediment samples
8.	R/V "Dolphin"	22-27 June 1970	Chemical water analyses, current and water temperature measurements, fish and benthic organism samples; sediment samples

6.1 Chemical

Most important work on the chemical aspects of the ocean was carried out in the cooperative cruises with Sandy Hook Marine Laboratory on the R/V Dolphin. These cruises were of a cooperative nature, hence only data immediately available were recorded. The remaining work on salinity was carried out at Sandy Hook Marine Laboratory and results were not made available to us.

Dissolved oxygen (D.O.) tests were made immediately and these are summarized in Table 13. D.O. tests were made by titration, immdiately after sampling, using the Austerberg modified Winkler technique. Oxygen levels were generally high near the surface. It is important to note that D.O. levels were significantly lower in the region from 100 to 500 fathoms in depth than for areas of either deeper or more shallow water. Had waste materials been deposited here without this study, the natural assumption would have been that wastes were demanding oxygen. This oxygen sag is a naturally occurring one, prevalent in this particular region.

In general, the bottom area has a greater dispersion of D.O. than the surface. This can really be deduced by comparison of the standard deviation of the bottom D.O.s with those on the surface, (Table 14).

In every set of top and bottom D.O. measurements, the surface water held a greater quantity of D.O. At times theses quantitites approached one another, e.g. in cruise FI-SH 3, station 23.

6.2 Bilogical

Other trawls were executed in a number of locations in the test area and, at times, outside these areas on all three FI-SH Cruises. The data from these cruises are summarized in Table 14 in terms of total

Table 13

DISSOLVED OXYGEN MEASUREMENTS*

Cruise Station	FI-SH 1		FI-SH 2		FI-SH 3	
	Top	Bottom	Top	Bottom	Top	Bottom
12	9.5	4.9	9.1	5.5	6.7	4.4
16			8.8	7.3	5.5	3.9
20			9.0	8.2	8.4	6.5
21			–	8.35		
22			–	–		
17			7.3	6.65		
11	10.2	7.3				
7	–	7.2				
4	9.9	7.1				
2	9.8	8.1				
8	–	5.9				
10					8.3	7.9
6					5.9	4.0
3					6.6	5.6
1					–	6.8
19					–	4.25
23					8.1	8.0
Mean	9.85	6.86	8.55	7.20	7.07	5.70
Std. Dev.	0.28	1.33	0.84	1.17	1.19	1.65

*Measurements made using Austerburg modified Winkler system which compensates for nitrates.

Table 14

SUMMARY OF BIOMASS DATA FROM FI-SH CRUISES 1, 2 and 3

Fish Cruise	(Trawl No.)	Bottom Area Covered (m^2)	Measured Biomass (kg)	V Biomass Density (g/m^2)	X Depth (m)
1	1	75,867	71.6	.944	98
	2	75,867	215.5	2.84	115
	3	75,867	90.6	1.19	189
2	1	56,900	79.38	1.40	149
	2	56,900	80.36	1.41	182
	3	56,900	42.92	0.75	237
	4	64,545	10.21	1.47	269
3	1	85,330	10.64	1.25	97
	2	107,479	34.36	0.32	100
	3	75,867	31.83	0.42	255
	4	82,190	112.27	1.37	258

Statistical Data.

$\bar{X}$ (mean depth) = 176 σ_x = 66

$\bar{Y}$ (means Biomass Density) = 1.21 σ_y = 0.64

Pearsons Coeffieient of Correlation = -.1571

biomass. Detailed information on specific species captured are contained in Tables 15, 16, and 17. The common and scientific names for the macrofauna are contained in Table 18.

Pearson's correlation coefficient was applied to obtain a measure of the effect of depth on macrofauna biomass in the area.

The correlation coefficient of -.1571 indicates that the biomass falls off with depth (because of the negative sign); however, there is is no very clear indication that correlation between depth and biomass is good. A correlative of -1 would say that biomass definitely varies with depth in a predictable manner. Species become important only if there is some definite means of delineating the importance of that particular species to the overall systems and there is currently no way to do this completely.

Commercial value of the species is the immediate (and perhaps deceiving) means of evaluating particular species. Some later significance may be attached to these baseline data for comparisons. It was desirable to trawl deeper than the 148 fathoms (888 feet, 269 meters) were we actually able to trawl; however, limitations on the equipment (namely the steel cable length) on the R/V Dolphin prohibited trawls as deep as 1200 ft. or more. Plans were to extend the depth capability by installing new cable had the program continued.

6.3 Hydrographical

Current meters were used to determine the speed and direction of current near the bottom. To accomplish this two Hydroproducts Model 502B current meters were implanted on cruise FI3 on 30 October 1969 at 3H4-3794, 3H5-2786 in 1120 feet of water and at 3H4-3806, 3H5-2786 in 800 feet of water.

These were moored using the system shown in Figure 9. A surface buoy provided vertical suspension of the meter system.

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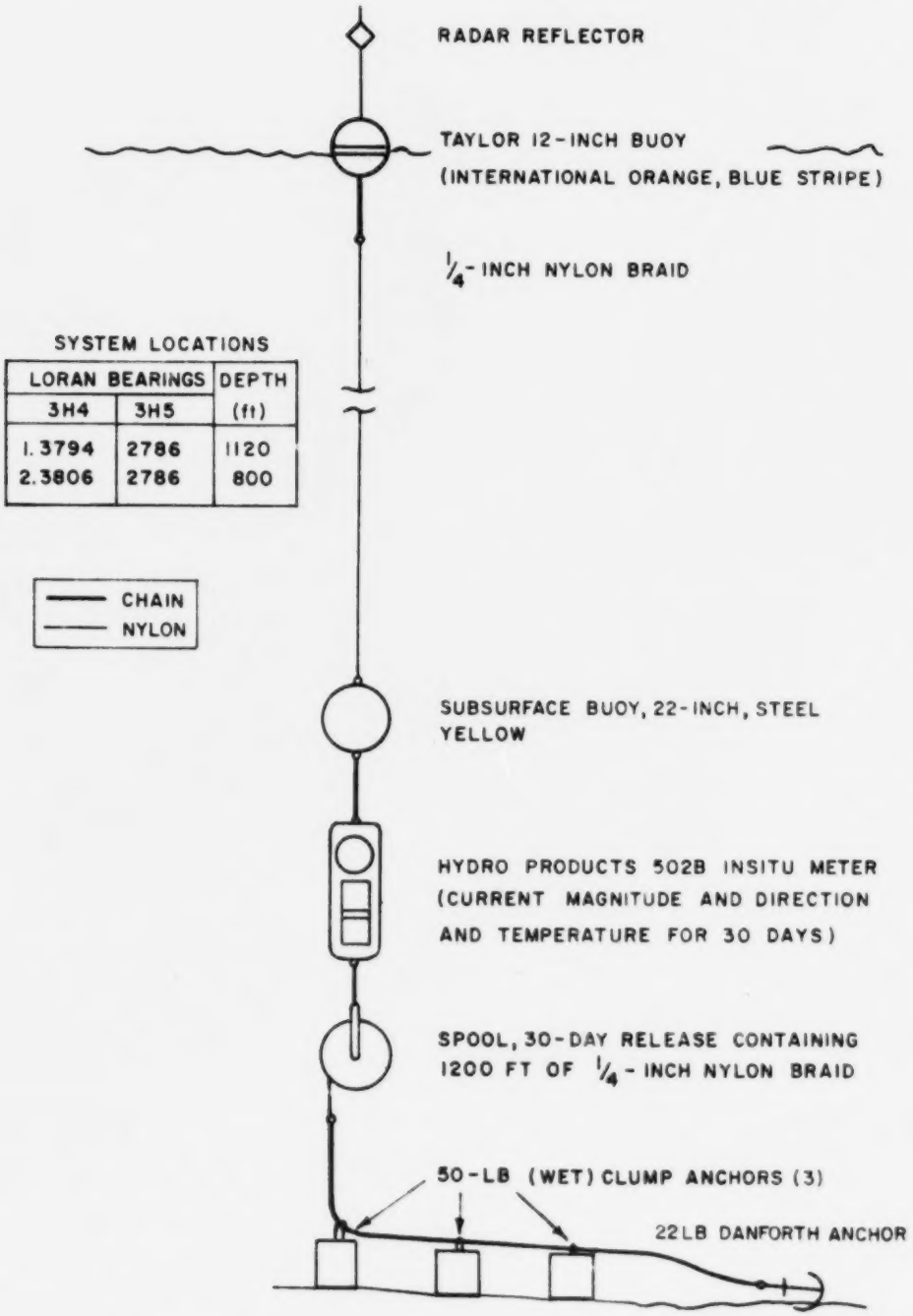

Fig. 9. Buoy System Employed For Current Measurements

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Table 15

LISTING OF TRAWL DATA FROM FI-SH 1 (19 May 1970)

Species	59 Fathoms (108 m) Station 2 to 1 (Start 0023 hr.) Total No.	Total Mass (kg)	Range Lengths (mm)	63 Fathoms (124 m) Station 4 to 5 (Start 1700 hr.) Total No.	Total Mass (kg)	Range Lengths (mm)	104 Fathoms (190 m) Station 8 to 7 (Start 1300 hr.) Total No.	Total Mass (kg)	Range Lengths (mm)
Vertebrates									
Goosefish	18	20.2	203-440	10	~14	294-670	1	2.0	528
Butterfish	330	20.0	136-196	*	67.5	157-205	5	--	147-212
Striped sea robin	262	13.2	156-247	6	0.2	146-206			
Spotted hake	36	9.5	242-362	20	5.0	240-365	23	8.6	235-378
Northern porgy	94	3.2	107-148	9	0.2	107-152			
4-Spot flounder	15	2.3	216-313	68	10.6	217-345	13	3.6	257-339
Gulf stream flounder	4	--	82-278	2	--	105	5	--	92-105
Witch flounder							***	15.9	203-298
Summer flounder				1	2.8	585			
Squirrel hake				16	2.9	252-393	27	6.3	273-393
Silver hake				6	2.0	295-422	39	7.7	162-350
Rosette skate				1	--	405	1	--	375
Clearnose skate	2	--	444-447	19	15.4	405-552			
Spotted scorpionfish							53	0.6	77-105
Spiny dog	15	3.2	328-469	**	85.3	160-283	13	2.3	280-481
Chain dogfish				2	--	410			
Atlantic mackerel	2	--	330-320	8	1.6	287-322			
Ocean pout	1	--	445						
Fawn cusk-eel	1	--	307						
American shad							1	--	420
American John Dory							12	--	65-262
Green eye							31	--	75-125
Beardfish							6	--	152-162
Armored sea robin							1	--	72
Invertebrates									
Loligo Pealii	20	--	--	40	--	--	10	0.1	--
Loligo ilex							61	3.6	--
Cancer borialus	10	--	33-165	32	8.2	--	78	15.9	--
Cancer irroratus				1	--	--			
Porcolean crabs				200	--		****	14.5	--
Lobster (homerus americanus)	1	--	--	2	--	95-116 (carapace)	11	9.5	108-193 (carapace)
Misc. starfish	>20	--	--						
Total measured biomass		71.6			215.5			90.6	

*5.5 smaller baskets
**3.5 bushels
***1 smaller
****1 bushel

Table 16

LISTING OF TRAWL DATA FROM FI-SH 2 (3 JUNE 1970)

Species	82 fathoms (149 m) 38° 42.5'N 73° 05.5'W (Start 1530 hr.)			100 fathoms (182 m) 38° 35.2'N 73° 13'W (Start 1330 hr.)			130 fathoms (237 m) 38° 35'N 73° 12'W (Start 1100 hr.)			148 fathoms (269 m) 38° 33'M 73° 09'W (Start 0930 hr.)		
	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)
Vertebrates												
Goosefish												
Butterfish							13	—	—	1		460
Striped sea robin												
Spotted hake	29	4.53	240-332									
Northern porgy												
4-Spot flounder	20	3.85	215-365	6	—	265-332						
Gulf stream flounder	3	—	110-125	9	—	98-162	1	—	120			
Witch flounder	35	—	214-513	–	23.1	200-298	–	24.4	191-431	4	—	215-355
Summer flounder												
Squirrel hake												
Silver hake	2	—	321-325	54	8.15	131-310	–	5.41	153-305	13	2.49	268-321
Rosette skate	2	—	375-389									
Clearnose skate												
Spotted scorpionfish	12	—	81-113	11	—	89-183	11	—	97-195	16	1.36	93-230
Spiny dogfish												
Chain dogfish												
Atlantic mackerel	—	47	106-310									
Ocean pout												
Fawn cusk-eel	1	—	258									
American shad												
American John Dory	1	—	70	1	—	77	3	—	104-212	1	—	244
Green eye	2	—	64-77	2	—	85-94	1	—	128			
Beardfish				4	—	141-160						
Armored sea robin	30	—	153-290	54	1.81	102-251	1	—	181			
Longnosed Grenadier							3	—	169-228	40	—	115-197
Common Grenadier										2	—	242-256
Invertebrates												
Loligo Pealii	12	—	—	4	—	—	—	2.49	—			
Loligo ilex	14	—	—	8	—	—	10	—	—			
Cancer borialus	63	19	—	—	28.5	—	18	6.32				
Cancer irroratus												
Porcolean crabs	14	—	—	—	13.6	—						
Lobster (Homerus americanus)	9	5	82-124	6	5.2	114-156	4	4.3	—	6	6.36	98-115
Misc. starfish										2	—	—
Octopus												
Total measured biomass		79.38			80.36			42.92			10.21	

Table 17

LISTING OF TRAWL DATA FROM FI-SH 3 (24 JUNE 1970)

Species	53 fathoms (97 m) 38° 33'N 73° 18'W (Start 1829 hr.)			55 fathoms (100 m) 38° 37'N 73° 17'W (Start 1615 hr.)			140 fathoms (255 m) 38° 38'N 73° 11'W (Start 1336 hr.)			142 fathoms (258 m) 38° 30'N 73° 17'W (Start 1930 hr.)		
	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)	Total No.	Total Mass (kg)	Range Lengths (mm)
Vertebrates												
Goosefish	2	1.81	280-425	3	2.04	295-375	15	16.8	317-540	12	23.5	400-718
Butterfish				–	17.6	145-240						
Striped sea robin												
Spotted hake	34	8.83	206-360	42	11.55	260-359	56	12	225-338	7	2.26	292-345
Northern porgy				3	—	123-155				1	—	130
4-Spot flounder	22	—	221-320	4	—	224-267	18	—	231-371	1	—	235
Gulf stream flounder							11	—	66-127	3	—	120
Witch flounder	2	—	384-393	4	—	224-267	24	—	212-460	—	13.6	220-548
Summer flounder												
Squirrel hake	2	—	253-295	1	—	277	6	1.67	199-342	—	32.81	165-404
Silver hake	4	—	241-380	2	—	290-378	4	—	276-322			
Rosette skate	3	—	361-400				1	—	—		—	216
Clearnose skate	3	—	470-520	9	—	436-495						
Spotted scorpionfish	1	—	87				5	—	87-104	15	—	98-180
Spiny dogfish				1	—	270						
Chain dogfish	2	—	390-401	1	—	300						
Atlantic mackerel												
Ocean powt												
Fawn cusk-eel												
American shad												
American John Dory							1	—	—	2	—	191-262
Green eye												
Beardfish												
Armored sea robin							3	—	66-146	1	—	284
Longnosed Grenadier							1	—	—			
Common Grenadier												
Invertebrates												
Loligo Pealii	10 combined species						13	1.36		30 combined		
Loligo ilex							1					
Cancer borialus	6	—	—							—	23.1	–
Cancer irroratus												
Porcolean crabs												
Lobster (Homerus americanus)	2	—	small	3	3.17	116-160	2	—	124,145	16	17.0*	
Misc. starfish												
Octopus												
Total measured biomass		10.64			34.36			31.83			112.27	

* Weight estimated due to no recorded data

Table 18

COMMON AND SCIENTIFIC NAMES FOR MACROFAUNA

Vertebrates

Goosefish (Lophius americanus)
Butterfish (Poronotus triacanthus)
Striped sea robin (Prionotus evolans)
Spotted hake (Urophycis regius)
Northern porgy (Stenotomus chrysops)
4-Spot flounder (Paralichthys oblongus)
Gulf stream flounder (Citharrichtys arctifrone)
Witch flounder (Glyptocephalus cynoglossus)
Summer flounder (Paralichthys dentatus)
Squirrel hake (Urophycis chuss)
Silver hake (Merluccius bilinearie)
Rosette skate (Raja garmani)
Clearnose skate (Raja eglanteria)
Spotted scorpionfish (Scorpaena plumieri)
Spiny dogfis (Squalus acanthias)
Chain dofish (Scyliorhinos retifer)
Atlantic mackerel (Scomber scombrus)
Ocea pout (Macrozoarces americanus)
Fawn cusk-eel (Lepophidium cervinum)
American shad (Alosa sapidissima)
American John Dory (Zenopsis ocellata)
Green eye
Beardfish (Polymixia Lowei)
Armored sea robin (Peristedion miniatum)
Longnosed Grenadier
Common Grenadier (also Marlin spike) (Nezumia bairdi)

A corrosive time-release link provided for the release of the meter buoy and spool from the anchor after an immersion period of 30 days. The buoy, meter and spool were designed to come to the surface, while trailing a line still attached to the anchor.

A notice was placed on the buoy offering a reqard for return of the system including the meter.

Recovery of the meters was attempted on cruise F14, during which time an unproductive search was made of the area.

Cruise 5 was made for the same purpose, but with much greater effort. This area was combed using a daisy search pattern on 6 December from the USCGC Rockaway with full lookout once more without sighting the buoys.

The reasons for loss of these instruments are not completely understood, and it is not likely at this time that any positive conclusion will be achieved. Display of surface buoys at this location we now understand, an invitation for removal of the instruments. Any future efforts for measurements in this manner should include a coded, signal release system probably with a disposable anchor system.

Measurements of current were made during the last three cruises (cruises 6,7 and 8) using a tethered measuring system. Results were obtained by compensation for ships drift while suspending the current meter slightly off the bottom. Results are shown in Table 19. Indication are that currents move off the shelf toward deeper water.

Table 19
CURRENT DIRECTION AND SPEED NEAR THE BOTTOM
(FI-SH-1)

Station	Nominal Depth (Fathoms)	(Meters)	Current (Knots)	Direction* (° True)
2	59	107	.890	143
4	68	124	.740	110
7	122	222	.540	112
11	240	437	.520	123
12	248	451	.570	140
8	104	189	.433	175

*This direction is the one in which current flows toward (not from).

Current Measurements by Seabed and Surface Drifters

Drifter deposits and recoveries are indicated in Table 20. 800 drifters were releases as a part of the program; 400 each of surface bottles and Woodhead seabed drifters. Of 800 drifters deposited, only eight were recovered, six bottles and two seabed drifters. Of these eight, six were bottles deposited in the general area studied. None of the seabed drifters deposited at stations in the test area were recoverd. The two recovered were deposited *on* the shelf and were found on the edge of Wilmington Canyon in the nets of a trawler.

Drift appears to be consistently off-shore from the results of drifter deposits. An in-shore drift would have resulted in more recoveries either from trawlers (as was the case with the two recoveries reported) or from land masses, none of which actually occurred.

Further evidence of off-shore drift was made by detritus drift on the curise 2 where direct observations were made at depths to 1800 feet. Currents were observed to be going into approximatley the SW at speeds of about 0.25 knots.

Table 20

DRIFTER RECOVERY RESUME FOR CRUISES FI 1 THROUGH FI 8

Cruise	Number Deposited	Number Recovered	Location Recovered	Distance Traveled (Nautical Miles)	Time to Recovery (Days)	Speed nm/day	Speed nm/hour
FI 1	100 each	1 bottle	Bermuda	650	215	3.023	.125
		1 bottle	Portugal	3000	655	4.511	.1908
FI 2	None						
FI 3	50 each	1 bottle	Bermuda	650	106	6.132	.255
		1 bottle	Bermuda	650	155	4.193	0.174
FI 4	50 each	None					
FI 5	None						
FI 6	100 each	*1 bottle	Sandbridge Beach, Va.	280	148	1.958	0.081
	(25 ea. on slope 75 ea. on shelf)	*1 seabed	38° 23'N 73° 28'W	17	29	0.586	0.024
		*1 seabed	38° 29'N 73° 28'W	14.5	28	0.517	0.021
FI 7	None						
FI 8	100 each (25 ea. on Slope 75 ea. on Shelf)	*1 bottle	Nag's Head, N.C	310	47	6.595	0.274
		*1 bottle	Kitty Hawk, N.C.	315	55	5.727	0.238

Note: Speed are minimum, the path and time to deposit being unknown.

*Recoveries from drifters deposited on shelf.

Temperatures

Temperature observations were made on the RV Dolphin cruises (FI 6, 7 and 8), using a Spilhaus bathythermograph. The results of these these are summarized in figures 10,11, and 12 that represent combined plots for each of the three cruises.

Some interesting observations from these readings are that a warm water intrusion is present in the region of 50 to 100 meters in FI cruise 6 (FI-SH 1) and then during all of these cruises the water temperatures from a depth of 150 meters downward were all nearly identical and less than 12°C. This region appears quite stable in temperature during this time of the year. This stable condition, if it exists the entire year, would offer the advantage of better description of interaction between effluent and the environments.

6.4 Geographical

Direct observation from the Ben Franklin (see examples in appendix B) at depths to 1800 ft. indicate that some areas of the ocean floor had relatively small currents, probably less than one knot as deduced from bottom conditions. Others did contain some scouring marks which indicated currents up to 2 knots. These were closer to the shelf break. Observations of the drift of detritus indicated current to be about 0.25 knots at the time of observation.

Depths in the area appear to be as presented in the U.S Geodetic Survey Chart of the area. While these data are several decades old, they appear to remain reasonably accurate.

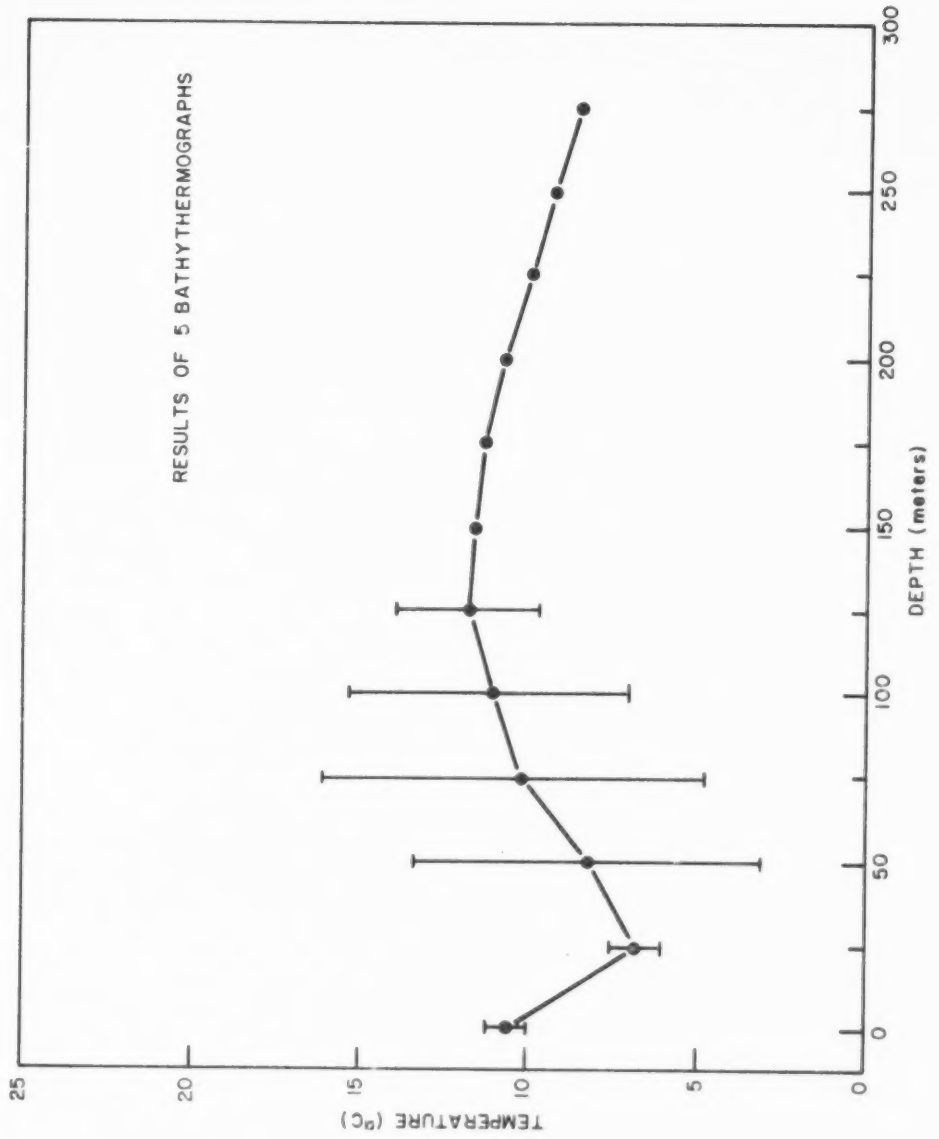

Fig. 10. MEAN AND STANDARD DEVIATION OF TEMPERATURE VS. DEPTH - FI-SH 1

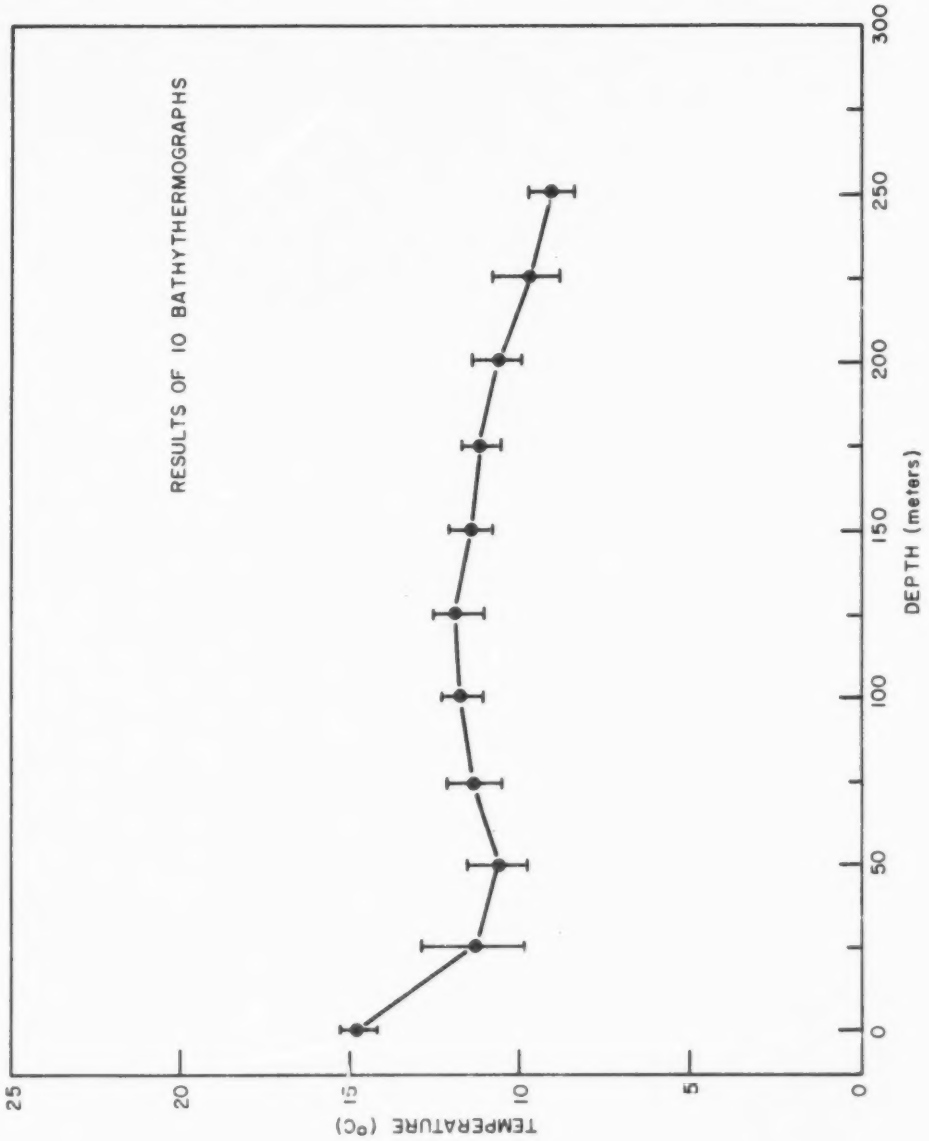

Fig. 11. MEAN AND STANDARD DEVIATION OF TEMPERATURE VS. DEPTH - FI-SH 2

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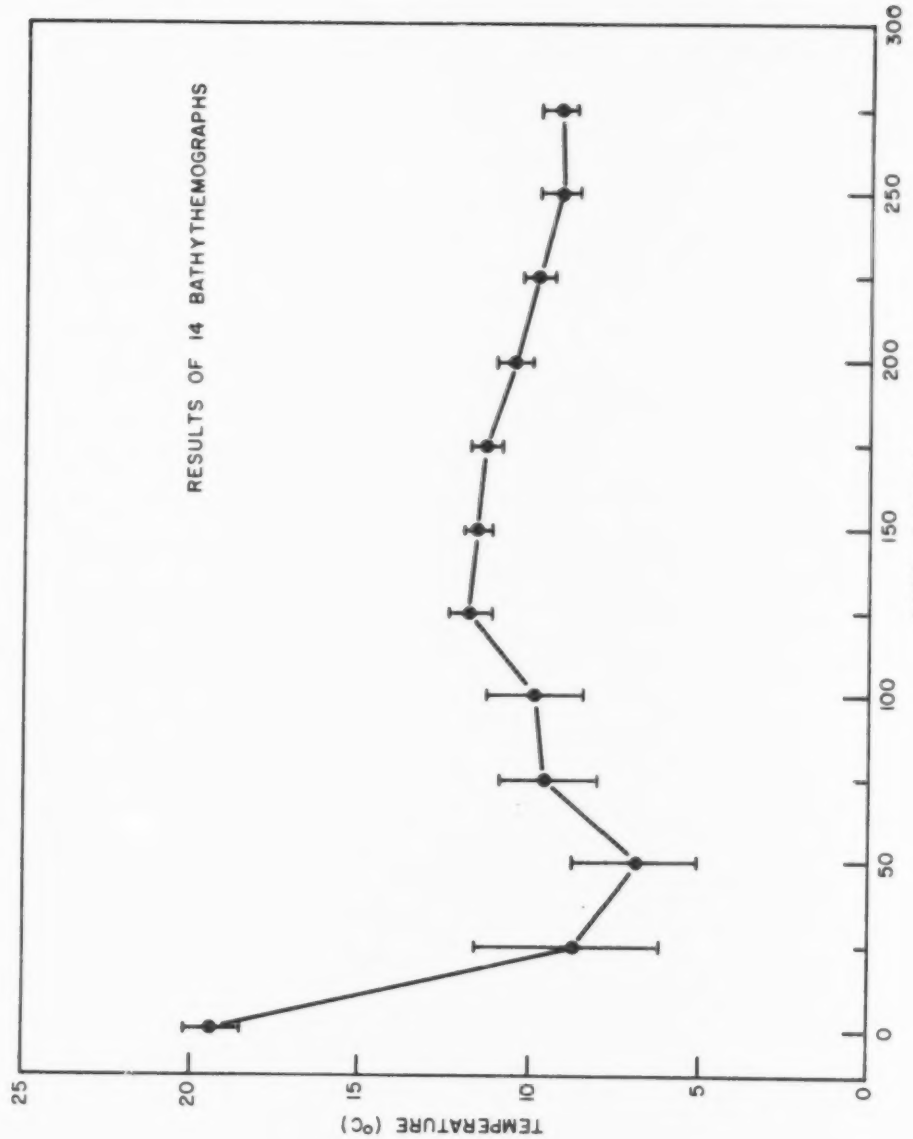

Fig. 12. MEANS AND STANDARD DEVIATION OF TEMPERATURE VS. DEPTH - FI-SH 3

7. COSTS

Preliminary cost estimates were made for the system in 1969[30]. At that time a large part of the fundamental design data, such as waste volume, concentration, and composition, as well as route, location and length and number of input stations were still unknown. Using ranges of assumption for these unknowns and general cost data available for existing pipeline systems produced the following cost estimates:

PRELIMINARY COST ESTIMATES JULY 1969 (REF. 30)

Pipe Size:	24" - 30"	36" - 48"
Est. Flow:	8 - 12 mgd	16 - 40 mgd
Est. Capital Costs:	$80 mm	$130 mm

A much better defined picture of the overall system has now been developed as a result of this year's work, even though there is still much information required before it would be possible to develop a completely detailed final design. Table 21 summarized an updated estimate based on the results of this year's work. It is somewhat lower than the initial rough estimate.

Experience factors play an important part in costing any system, particularly for a system such as this, which is large geographically and costly in terms of lumped capital outlay. The $75 million estimate for the system was arrived at using the experience and data available from a recent study by Braun and Cary Inc. on transporting Delaware River spoils through long lines[5]. In addition, the help and experience of the Williams Brothers Co., a pipelaying firm with varied background in underwater and slurry transport by pipeline was incorporated[31,32].

Table 21 contains a breakdown of capital costs. It can be seen that the 36" pipe and its laying are the principal cost items, representing. approximately 80% of the total capital required. herein also lies

Table 21
CAPITAL COST SUMMARY

1. Pipe 36" (844,880 ft. total)		
Land Section 316.800 ft. @$30/ft.		9,470,000
Undersea Section 422,400 ft. @$80/ft.		33,800,000
2. Pipe Installation		
Land Section 316,800 ft. @$8/ft.		2,534,000
Undersea Section 422,400 ft. @$25/ft.		10,550,000
3. Pumping Stations - 4 @$120,000		480,000
4. Diluent Feeder Station		120,000
5. Instrumentation		200,000
6. Contingency @30%		17,400,000
	Total	74,554,000
	say,	75,000,000

the greatest possibility for cost changes. At present, pending further evaluation, it would appear that polyester-glass reinforced pipe at ca. $30 per foot would be the least expensive yet suitable pipe material for the overland part of the system. Polyolefin pipe at ca. $80 per foot would tentatively appear to be the choice for the undersea portion. Pipe installation (laying, anchoring and burial) may represent from 20-50% of the cost of the pipe itself. Therefore, 28% of the pipe cost was used for an average. Pumping station costs are not a significant factor - even in the Braun and Cary study where six times the flow velocity was used to keep sand and gravel in turbulent suspension. The instrumentation costs, also a relatively insignificant part of the overall cost, of the wasteline system were arrive at by tripling the figure used in the Braun and Cary study. Whereas a contingency of 20-25% might ordinarily be adequate for a project of this size, it was felt that 30% gave a more realistic coverage for the uncertainties yet present for the deep ocean laying operations.

Land use is based on the rental of 872 acres of right-of-way across predominantly rural (with some sub-urban) terrain in central New Jersey (i.e., this is 10% per year of the $2,616,000 estimated value of 872 acres having an average current value of $3,000 per acre). No rental is assumed for the receiving spoil ground since its present and future allocation is already set for the use of spoil handling.

Power costs are based on a required total B.H.P. of 32 or 1,572,000 KWH/yr. at $.007/KWH. (Power costs are $.006/KWH for 4,160 volt service from Philadelphia Electric Company).

Labor costs are based on $12,000/yr for foreman; $10,000/yr for general operators and maintenance men; and $16,000 as the average annual labor cost for six administrative employees.

Capital charges (principal and interest) are based on paying the $75,000,000 capital expense over a 30 year period at a prime interest rate of 8%.

Table 22 shows the anticipated annual costs derived from the above guidelines.

The total disposal cost for waste concentrates are presented in Table 23. the cost drops from a current $3.52/1,000 gal to $1.85/1000 gal of concentrates in the year 2,000. it should be remembered from Section 3 that the volume of waste concentrates collected increases yet, the amount of solids drops off substantially then increases slowly as a result of the diminution in the dense (40 wt. %) dredge spoil volume. If credit is included for the removal of dilute wastes used for diluting the high solids content of the line, we get a value of $1.27 per 1,000 gallons of effluent transported over the 160 miles.

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Table 22

OPERATING COSTS ($/YEAR)

1. Land Use	
Station and Right-of-Way	262,000
2. Power	
1,572,000 KWH/yr @$.007/KWH	12,490
3. Labor	
10 Foremen, 30 Operators and Maintenance Men, 6 Administrators	516,000
4. Capital Charges - (Principal and interest paid over 30 years @8%/year	6,603,996
5. Operation and Maintenance Costs	
(vehicles, spare parts, tools, services, etc.)	100,000
Total	7,494,486

Table 23

TOTAL DISPOSAL COST FOR WASTE CONCENTRATES

	Year			
	1970	1980	1990	2000
Volume of Waste Concentrates (mgy) (Table 3)	2,109	2,647	3,417	3,994
Disposal Cost ($/1000 gal)*	3.52	2.79	2.17	1.85

TOTAL DISPOSAL COST FOR TOTAL EFFLUENT

Disposal Cost per 1,000 gal*. of effluent (5,840 mgy concentrates plus dilute waste diluent)	1.27	1.27	1.27	1.27

*For wastes at pickup point (Delaware River at Woodbury Creek)

The cost of barge disposal to sea from the Philadelphia Region as would be expected, exceeds the cost of pipeline disposal. The cost for disposing of Philadelphia's sewage sludge for example is currently (three year contract expires August 1970) $3.77/1,000 gals. This is for delivery to a point only 12 miles from the mouth of Delaware Bay. It is an additional 80 miles to the shelf-break. Costs for the barging of chemical wastes in lined barges undoubtedly would exceed this. Looking at another approach, published charges for a centralized chemical waste disposal service in the Delaware River Basin are from 3¢ to 30¢ for each gallon of waste treated; this comes to $30.00 to $300.00 per thousand gallons[33].

Other factors which must be considered of a pipeline alternative to barging, besides cost, are overall technical and ecological effectiveness. A pipeline is a single system, easily and conveniently monitored, either before, during, or after the wastes are put into the line. Barging is a highly distributed system not easily monitored in practice (with respect to content or point of release) because of geographical spread and irregularity of schedules.

Other factors which also must be considered between these alternatives are the value of releasing pre-diluted wastes over a wide area 1200 feet below the water's surface by pipeline, as opposed to releases of highly concentrated wastes (necessary to reduce the number of barge trips) into surface waters.

8. CONCLUSIONS AND RECOMMENDATIONS

In terms of engineering, legal and economic considerations a pipeline to the continental slope from the Delaware Valley is feasible. The construction of such a line across a land path to the coastal terminus and from this terminus to the continental slope may be accomplished.

Operations as predicted would result in considerable savings over existing methods of disposal by barge.

A limited baseline study indicates that currents on the bottom, beyond the edge of the continental slope, are off-shore as evidenced by current measurements and by deposition if seabed drifters with minimal recovery.

Observations of the life in this area by submersible and by otter trawls provide some base-line data on the area. The population and biomass density will provide frames for future reference. Main fishing interest in the immediate area is in fin fish and lobster, and these from foreign sources. These species apparently would be little affected by the types of wastes being considered, but proof of this would be the subject of further work. No bivalve shellfishing is done in this area.

The area is not as productive as in-shore areas of the continental shelf or in estuaries where much waste deposition now takes place.

Further examination of this method of disposal is justified, if not for a permanent disposal method, to serve as an interim method until such time as recyling or more appropriate disposal methods than are now used become practicable.

Supplemental base-line data are imperative. Particular attention should be paid to year-round population studies and to possible interaction of benthic poplulations with various candidates for inclusion tne pipeline.

Actual construction and use of such a pipeline as a pilot project, with controlled use of the line and thorough examination of the effects on ecosystems, could go a long way in extending man's knowledge of the oceans and how they might safely be used as a resource for waste management.

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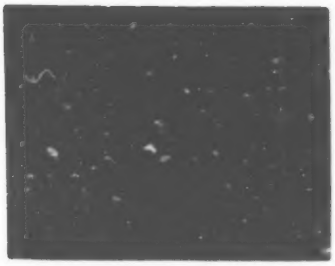

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Appendix

A

PUBLIC PRESENTATIONS ON OCEAN

WASTE DISPOSAL AND DISPOSAL BY PIPELINE

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA, PENNA. 19103

APPENDIX A
PUBLIC PRESENTATIONS ON OCEAN WASTE DISPOSAL AND DISPOSAL BY PIPELINE

Public interest and concern about the state of the environment particularly marine water pollution has become very intense as a result of numerous recent reported findings on adverse pollution effects.

Because of this, exceptionally high public interest has been shown in this project since its very inception two years ago. This was materially heightened during the past year, when the research work with FWQA funding moved from purely paper studies to actual experimental work on the continental slope.

The usage and findings of the research submersible "Ben Franklin" on the slope bottom in particular have been of great interest to the pbulic, as well as to technical and government groups.

It is felt that all of the attention and efforts that have been made to present the philosphy and need for studies such as this have been necessary and well spent.

The following list covers the major public information presentations given to date on various aspects of ocean waste disposal, collecting and piping wastes to sea, and marine pollution.

Date	Public Presentations	Speakers (s)
21 Oct 1968	Annual Delaware River Basin Water Resources Conference, Pocono Manor, Pennsylvania	R. A. Erb
12 Dec 1968	Water Resources Seminar, University of Delaware, Newark, Delaware	R. A. Erb
23 Jan 1969	Mid-Atlantic Watershed Meeting, Philadelphia, Pennsylvania	R. A. Erb
20 Feb 1969	U.S.P.H.S. Region II Shellfish Sanitation Meeting, Dover, Delaware	R. A. Erb
2 Apr 1969	Franklin Institute Membership Dinner, Philadephia, Pennsylvania	R. A. Erb
2 Oct 1969	AIChE Student Chapter Meeting, University of Delaware, Newark, Delaware	D. Pindzola
27 Oct 1969	Annual Meeting of the Water Resources Association of the Delaware River Basin, Buck Hill Falls, Pennsylvania	R. A. Erb
3 Nov 1969	Philadelphia Naval Reserve Officers Monthly Meeting, Philadelphia, Pennsylvania	C. T. Davey and D. Pindzola
25 Nov 1969	American Association of University Women Wilmington Delaware Branch, Wilmington, Delaware	D. Pindzola
21 Nov 1970	Instrument Society of America, Philadelphia Section Meeting, Philadelphia, Pennsylvania	C. T. Davey
13 Mar 1970	Briefing for the U.S. Senate Subcommittee on Air and Water Pollution, covering Ocean Waste Disposal, Washington, D.C.	D. Pindzola, M. B. Zisfein and and P. S. Francis
3 Apr 1970	5th Mid Atlantic Regional Meeting American Chemical Society, Ocean and Estuary Chemistry Session, University of Delaware, Newark, Delaware	D. Pindzola
25 Mar 1970	National Industrial Solid Waste Conference Houston, Texas, Ocean Disposal Section	D. Pindzola
16 Apr 1970	Ocean Engineering Seminar, University of Rhode Island, Kingston, Rhode Island	D. Pindzola and C. T. Davey
16 Apr 1970	FWQA National Marine Water Quality Laboratory, West Kingston, Rhode Island	D. Pindzola and C. T. Davey

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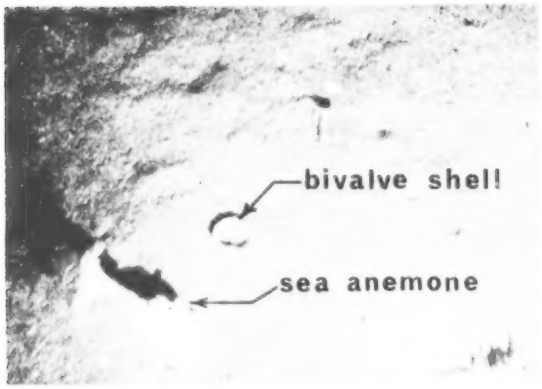
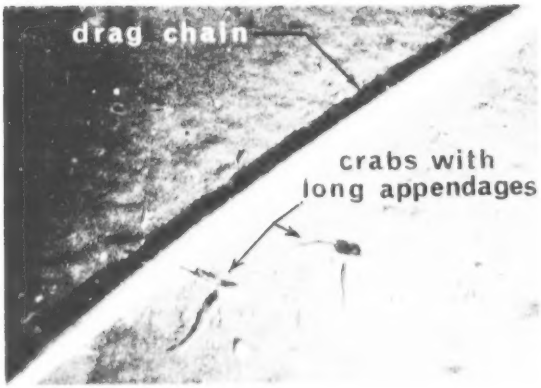
Appendix

B

PHOTOS MADE DURING THE FIRST DIRECT OBSERVATIONS
OF THE CONTINENTAL SLOPE BOTTOM



(a) 150m (492 ft)



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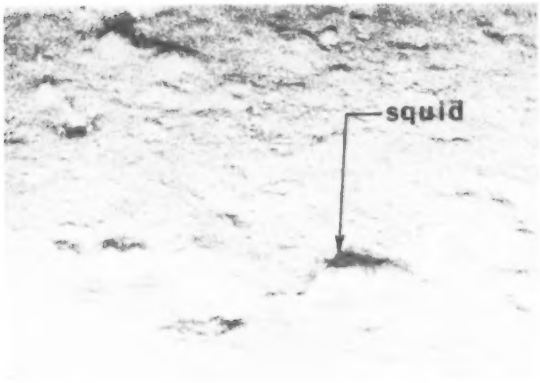
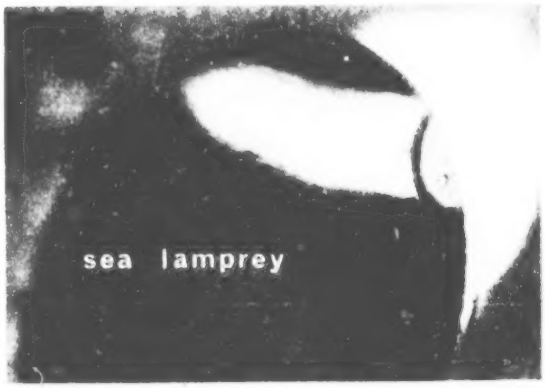
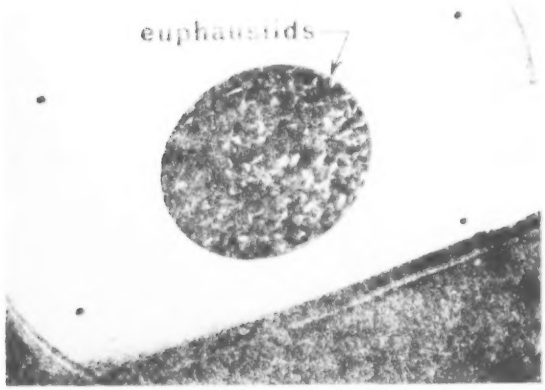


(c) 150m (492 ft)



(d) 210m (689 ft)

(e) 365m (1200 ft)



(f) 365m (1200 ft)

Miscellaneous biota in the study region, as photographed during the exploratory dive in the Ben Franklin (8,9 September 1969).